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## SOME CHEMICAL ASPECTS OF THE CANCER PROBLEM<sup>1</sup>

By Dr. CARL VOEGTLIN

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IN the lectures on chemotherapy I have attempted to bring out the importance of the study of the *selective* action of chemotherapeutic agents on specific cells. There is no doubt that the ultimate understanding of the mode of action of chemotherapeutic agents will depend on knowledge concerning the interaction between drug and cells, with particular reference to the physiological and biochemical changes resulting from this interaction. It is quite evident too that progress in this difficult field will depend on more extensive knowledge of the physiology and biochemistry of the cells concerned in the chemotherapeutic process.

To-day, I wish to discuss briefly certain chemical problems in cancer research. You may wonder what connection chemotherapy has with cancer research. In reply it can be stated that many phases of fundamental cancer research deal with the study of normal and malignant cells and their reactions to chemical changes

in their environment. As in chemotherapy, some of these problems are concerned with the selective action of certain chemical agents on specific types of cells. In fact, I am convinced that work along these fundamental chemical lines holds out hope for a gradual solution of certain important aspects of the cancer problem. The purpose of the following discussion is to describe the experimental evidence upon which this belief is based.

For better orientation the subject can be divided into three topics: first, chemical carcinogenesis, that is, the transformation by chemicals of normal cells into malignant cells; second, the chemical characteristics of tumors; and third, attempts to cure animals with cancer by chemical treatment.

### CHEMICAL CARCINOGENESIS

It has been known for a very long time that workers engaged in certain occupations or industries are apt to develop malignant tumors in certain organs. These

<sup>1</sup> Herter lecture, New York University College of Medicine, April 21, 1938.

so-called occupational cancers are frequent in chimney-sweeps exposed to soot, in workmen chronically exposed to coal tar, in spinners exposed to certain oils and in workers in dye factories. During the world war Yamagiwa and Ichikawa reported the first successful production of tar cancer in rabbits following the prolonged exposure of the skin to coal tar. This important observation at once raised the question as to whether the carcinogenic properties of coal tar were due to the presence in tar of definite carcinogenic chemicals. As is well known, the work of Kennaway, Cook and associates finally led to the isolation of 3,4 benzpyrene which is now recognized as the active carcinogenic substance in coal tar. It was easily shown that the prolonged application of a benzene solution of benzpyrene to the skin of mice caused malignant skin tumors. Now benzpyrene can be regarded as a derivative of 1,2-benzanthracene to which another benzene ring is attached. The English workers found that 1,2-benzanthracene had only feeble carcinogenic properties. However, the introduction of another benzene ring in the 5,6 position yielded 1,2,5,6 dibenzanthracene, which is quite active. In the course of a few years the English School synthesized a large number of related aromatic hydrocarbons for a systematic study of the relation between chemical structure and carcinogenic properties. There is no need of giving a detailed account of this extensive and painstaking investigation.

Perhaps the most significant observation made was the discovery of the powerful carcinogenic activity of methyl cholanthrene. This compound is a 5-methyl 1,2 benzanthracene containing a 5 carbon ring attached to the 6 and 10 position. A significant feature of the configuration of methyl cholanthrene is the similarity of its ring structure to that of a bile acid, namely, desoxycholic acid. In fact, Wieland first prepared methyl cholanthrene from desoxycholic acid by a four step reaction. This chemical relationship of the two substances suggested the idea that a pathological deviation in the bile acid or cholesterol metabolism might lead to the formation of methyl cholanthrene in the body and thus could explain the cause of some spontaneous malignant tumors. While this attractive hypothesis may still be true it has lost some of its probability due to the recent collaborative work of the Public Health Service with the Harvard Department of Chemistry. Fieser and his coworkers have synthesized a series of compounds which have been tested as to their carcinogenic power by Shear. It is perfectly clear that the 5 carbon ring, a characteristic feature of bile acids, is not an essential requirement for carcinogenicity, since the introduction of a methyl group in the 10 position of 1,2 benzanthracene is sufficient to endow the resulting compound with an

activity of about the same grade as that of methyl cholanthrene. Lengthening of the carbon chain in the 10 position diminishes activity and shifting the methyl group from the 10 to the 5 position practically abolishes activity. It might be argued that methyl cholanthrene is formed from desoxycholic acid in the body to be degraded still further to 10 methyl 1,2 benzanthracene. The direct chemical conversion of methyl cholanthrene into 10 methyl 1,2-benzanthracene appears to be impossible, but whether this can occur in the animal body is another question. It is well to remember that the tissues can accomplish with ease chemical transformations which present-day chemistry has failed to perform in the test-tube. It is, therefore, still conceivable that a pathological bile acid metabolism may give rise to the formation of methyl cholanthrene or, still simpler, 1,2 benzanthracene, or possibly phenanthrene derivatives with high carcinogenic activity. A theoretically possible alternative would be the formation of similar carcinogenic substances as a result of a pathological course in the biochemical synthesis of sterols, since it is known that the animal body has the capacity to synthesize cholesterol and bile acids from simpler compounds. Progress in these directions will probably be slow and the foregoing remarks are intended to emphasize the value of the biological viewpoint in the study of chemical carcinogenesis.

Evidence relating the biological action of carcinogenic hydrocarbons and sex hormones was first put forward by Cook and coworkers, who discovered that 2,3 benzpyrene and 5,6-cyclo penteno-1,2-benzanthracene are mildly estrogenic. These chemicals, therefore, possess the dual activity of carcinogenesis and estrogenesis.

The first instance of the production of malignant tumors by a naturally occurring chemical of known structure was reported by Lacassagne. He showed that the long-continued treatment of male mice with large doses of estrin results in mammary cancer. This is a very significant observation, since Little reports that in over five thousand mice in his colony spontaneous mammary tumors occurred only in the females and not in a single male. Both Gardner and Loeb and their associates have clearly shown that the carcinogenic action of estrogens is proportional to the size of the dose. Furthermore, Gardner and coworkers made the paradoxical observation of the production of seven sarcomas in mice at the site of the subcutaneous injection of estrogens. In a paper which has just appeared they report the production of carcinoma of the cervix of the uterus in the mouse 319 days following the repeated subcutaneous injection of large doses of estradiol benzoate. This is in harmony with Loeb's previous observation of precancerous cervix lesions following estrogen injections.

The preceding account has dealt with carcinogens which have a chemical relationship to certain naturally occurring substances. Brief reference will now be made to chemicals which are completely foreign to the animal body, yet can induce malignant tumors.

2-amino-5-azotoluene is such an example. If a solution of this dye in olive oil is mixed with the diet of rats, malignant liver tumors are produced after about 10 months of such feeding. Shear has produced these tumors in mice by several subcutaneous implantations of the dye in solid form. Due to its low solubility this deposit is absorbed very slowly in the course of weeks. Tumor production is always accompanied by a great enlargement of the liver. The precancerous changes consist in necrosis followed by proliferation of bile duct epithelium and sinus formation. The malignant cells can easily be recognized as large cells surrounded by the smaller normal hepatic cells. These tumors have been successfully transplanted to normal animals, a fact which is additional proof of the malignant nature of these tumors. Dr. Emmart has succeeded in cultivating this tumor *in vitro* for prolonged periods. The interesting feature of the carcinogenic action of amino azotoluene is its selective action upon the liver after oral or subcutaneous administration of the dye. The high solubility of the dye in fats and lipoids may be a factor in this selective action.

In a recent paper it is reported that "butter yellow," an azo dye closely related to amino azotoluene, will induce liver tumors in rats. Confirmation of this claim would justify discontinuation of the use of this dye for coloring butter.

Another matter of practical concern is the recent production of bladder tumors in dogs by Hueper and his colleagues. The so-called "aniline tumors" of the urinary bladder in workers in dye factories have been attributed to chronic exposure to aniline, benzidine and betanaphtylamine. However, all previous attempts to produce this disease in animals by any one of these three aromatic amines had failed. Hueper gave dogs commercial beta-naphtylamine by mouth and subcutaneously in increasing doses over a period of about 1½ to 2 years. By periodic cystoscopic examination and biopsies it was possible to follow the histopathological process leading to the formation of benign papilloma and finally to true carcinoma. It is significant that the time required to produce these malignant tumors is very long. This is consistent with the belief that these bladder tumors in dye workers also require many years of exposure. Commercial beta-naphtylamine always contains impurities, and it is therefore still an open question as to whether the tumors were produced by these impurities or by the naphtylamine *per se*.

In this connection it is important to emphasize the use of chemicals of the highest purity, if the work is designed to incriminate a definite chemical substance as carcinogenic agent. For example, triphenylbenzene was reported a few years ago as having carcinogenic properties, but Shear failed to obtain tumors by using a very carefully purified product. Furthermore, tetraphenylmethane has been reported as a slowly acting carcinogenic hydrocarbon. In this case also it would be advisable to perform experiments with a product of the highest attainable purity.

Two compounds which produce tumors very slowly are 1,2,5,6 dibenzacridine and 3,4,5,6 dibenzacridine. The first of these two compounds is of particular interest, since it is analogous to the potent 1,2,5,6 dibenzanthracene, in which one of the carbon atoms in the meso position is replaced by a nitrogen atom.

A very interesting instance of a chemical possessing both chemotherapeutic and carcinogenic properties is a styryl-quinoline derivative, studied by Browning and his coworkers. Subcutaneous injection of this water-soluble compound has produced sarcomas in 10 out of 19 mice. The substance is also trypanocidal. A closely related substance is trypanocidal, but not carcinogenic. A third related substance apparently lacks both properties. These observations illustrate the remarkable change in biological properties brought about by relatively slight changes in the chemical configuration of a compound.

At a recent scientific meeting Hall and Franks reported the production of osteo sarcoma in animals following the repeated subcutaneous injection of relatively large doses of acetylcholine. This work is now being repeated by the Public Health Service. Needless to say that confirmation of the production of malignant tumors by acetylcholine would present an intriguing subject for further study, since acetylcholine is a naturally occurring body constituent with a very specialized physiological function.

This brief account clearly demonstrates that work of the last few years has brought forth evidence of the carcinogenic action of a great variety of chemical compounds. There is good reason to believe that further work will add many more active compounds to this already long list.

We may now pass to a review of the various factors influencing the production of chemically induced tumors. Of these the study of the dose and time factors have received some attention, though the available information is by no means as complete as would be desirable. The results obtained with subcutaneous injections of such highly active compounds as dibenzanthracene, benzpyrene or methyl cholanthrene into rats or mice indicate that within a certain dosage range increase in the dose shortens the time at which tumors

appear. Thus Dunning, Curtis and Bullock found that in inbred rats injected with 2 mg of benzpyrene the mean time for the production of tumors was 201 days, whereas with 16 mg the mean time was cut in half—to 102 days. A further increase in the dose did not cause a further decrease in the latent period. The shortest latent periods on record vary between 30 to 45 days. On the other hand, Shear reports the production of a transplantable sarcoma in a mouse 14 months after the subcutaneous implantation of as little as 0.4 gamma dibenzanthracene in the form of a cholesterol pellet. The most reasonable explanation of this interesting observation is based on the assumption of a very slow and gradual release of the active agent from the pellet.

As to the susceptibility of various animal species to chemically induced tumors the available evidence points to wide variations. However, it should be emphasized that for various reasons most of the experimental work has dealt with mice and rats. Almost every type of malignant tumor seen in man has been induced chemically in mice and rats. Recently Shear has even produced brain tumors in mice by the implantation of methyl cholanthrene. These tumors appear to be gliomas. Chickens are quite susceptible to induced tumors, whereas rabbits are relatively resistant. Guinea pigs also are resistant, yet Haagensen and Krehbiel report four fibrosarcomas and four liposarcomas appearing one year after the subcutaneous injection of 3,4 benzpyrene. As already mentioned, dogs respond to beta naphthylamine with bladder tumors, but they seem to be more resistant to the highly active hydrocarbons. However, it may be that the latent period for tumor production in dogs may be a matter of years, whereas in mice it is a matter of weeks.

Until recently it was believed that all mice were about equally susceptible to chemically induced tumors. But the work of Andervont, of the Public Health Service, has revealed a striking difference in the average time of appearance of induced tumors in different highly inbred strains of mice. In one strain, for instance, 0.8 mg of dibenzanthracene produced tumors in every mouse within 28 weeks after injection, whereas in another strain no tumors appeared until 40 weeks after injection.

A systematic investigation with 8 different pure strain mice has failed to reveal a consistent correlation between susceptibility to induced subcutaneous tumors and susceptibility to spontaneous mammary tumors.

In the foregoing discussion reference has been made to several instances of chemically induced tumors arising in a tissue removed from the site of administration of the carcinogenic agent. A further example is the production of liver tumors by the subcutaneous injection

of 2-amino anthracene (Shear). Primary lung tumors have also been observed following the subcutaneous injection of dibenzanthracene into a certain pure strain of mice (Andervont). Many of these tumors appeared without the occurrence of subcutaneous tumors. This particular strain of mice has a high incidence of spontaneous lung tumors which appear relatively late in life, whereas the induced lung tumors occur much earlier. The most plausible explanation of this finding is that the dibenzanthracene, after absorption from the subcutaneous tissue, is carried to the lung where it accelerates the normally occurring carcinogenesis. This view receives support from the production of primary lung tumors by implantation of dibenzanthracene into the lungs of this mouse strain. It is of interest that the susceptibility to spontaneous lung tumors is inherited as a dominant factor. It would seem, therefore, that under certain circumstances the production of primary tumors of the lung may be attributed to the operation of at least two factors, first, an intrinsic hereditary susceptibility, and, second, an extrinsic chemical factor. This experimental evidence now serves as a basis for a comprehensive investigation by the Public Health Service of the causation of lung tumors, a problem which is of some concern in view of the apparent increase in the mortality from lung tumors in the population of this and other countries.

Parenthetically, it may be mentioned that some of the chemically induced primary lung tumors exhibit a typical adenomatous structure which on repeated transplantation of the tumors into other mice of the same strain changes to that characteristic of sarcoma.

#### MECHANISM OF CARCINOGENESIS

The production of malignant tumors by pure chemicals unquestionably represents a major advance in our knowledge of the causation of cancer. The next important problem is to explain how any one of these carcinogenic agents causes the transformation of normal into malignant cells. This question goes to the heart of the cancer problem and deserves intensive investigation from all points of view. At present the situation is quite obscure, in fact it is rather perplexing, because of the great variety of chemical carcinogens. From the purely chemical view-point it is utterly impossible to find a common characteristic of such diverse agents as the active hydrocarbons, estrine, aminoazotoluene, dibenzacridine, a styryl quinoline derivative, etc. Therefore, it is necessary to shift the interest to the study of the changes brought about in living normal cells under the influence of potent carcinogenic chemicals.

The outstanding biological characteristic of all malignant tumors is an apparently unrestrained capac-

ity for proliferation. Therefore, investigation has been directed to ascertain whether chemical carcinogens act as stimuli of cell proliferation. The results have been contradictory. On the basis of histological evidence Loeb believes that all carcinogenic agents induce a localized cell proliferation in susceptible animal species. Thus it has been shown that estrin in male mice stimulates the proliferation of mammary tissue. According to Gardner and coworkers small doses produce a normally appearing proliferation, whereas the large doses required for tumor production induce an abnormal proliferative response, evidence considered as supporting a direct carcinogenic action of estrogens on the mammary tissue. However, the view has also been advanced that this proliferation is brought about indirectly by the stimulating action of the sex hormone on the anterior lobe of the pituitary. This contention seems supported by the hypertrophy of the anterior lobe following treatment with large doses of estrine and the apparent increase in the incidence of spontaneous mammary cancer in mice by multiple transplants of the anterior pituitary lobe. In this connection it is interesting to note that Bagg has shown that the injection of extracts of the anterior pituitary, at certain seasons of the year, makes possible the induction of teratoma testis in fowl by intratesticular injections of zinc chloride.

A few attempts have recently been made to elucidate the action of carcinogenic hydrocarbons by studies on some lower organisms. Thus Hammett and Reimann have shown that methyl cholanthrene and dibenzanthracene do enhance the production of new growth in *Obelia geniculata*. Owen reports stimulation by dibenzanthracene of regeneration of cut segments in planaria, and Goldstein finds that the same agent stimulates the growth of a bacterium—*Escherichia communior*. It is obviously difficult, however, to utilize these observations for the explanation of carcinogenesis. On the other hand, it would seem that observations on tissue cultures have a more direct bearing on this problem. Therefore, Dr. Earle and I have carefully studied the action of highly purified methyl cholanthrene, prepared in Dr. Fieser's laboratory, on cultures of fibroblasts from the subcutaneous tissue of rats. The results obtained clearly show that methyl cholanthrene is highly toxic, since concentrations above one thousandth of a milligram per cc cause degenerative changes and the ultimate death of the cultures. Even extreme dilutions, such as two ten-thousandth milligram per cc, retard the growth rate of the cultures. It was impossible to detect the slightest stimulating effect under any conditions on the cultures. Subcutaneous injections of methyl cholanthrene into rats of the same strain produced a high percentage of sarcomas.

Haddow reports that the injection into young rats of one or two injections of about 10 mg of three carcinogenic agents, namely, 1,2,5,6 dibenzanthracene, 3,4 benzpyrene or 1,2,5,6 dibenzacridine, causes an immediate and prolonged retardation of growth, whereas three closely related non-carcinogenic substances failed to influence the growth rate. He also established the paradoxical fact that carcinogenic hydrocarbons injected daily in small doses inhibit the growth rate of transplanted tumors in rats.

Reimann observed that the combined application of parathiocresol and dibenzanthracene to the skin of mice lessened and delayed the incidence of skin tumors. This is of interest since thiocresol stimulates cell proliferation in the healing of superficial wounds. Therefore, consideration of the more significant results obtained with mammalian tissues would seem to indicate that at least some of the most potent chemical carcinogens do not act as stimuli for cell proliferation. Reimann is right in saying that stimulation of cell proliferation alone does not lead to neoplasia. Hence, the conversion of normal into malignant cells is probably due to profound metabolic changes, the nature of which are still obscure.

A few attempts have been made to change normal cells in tissue culture into cancer cells by exposure to carcinogenic hydrocarbons. The negative results obtained so far should not discourage further efforts in this direction, but we will have to keep in mind of course that conditions *in vitro* differ considerably from those prevailing in the animal body.

Practically nothing is known as to whether chemical carcinogens act as such, or whether they have to undergo chemical changes in the tissues before they acquire carcinogenic properties.

Finally, it should be mentioned that the proponents of the virus theory of cancer are inclined to regard chemical carcinogens as agents which merely render normal cells very susceptible to the action of ubiquitous carcinogenic viruses. Some of the arguments advanced in favor of this view are far from convincing because of incorrect generalizations. Gye in a recent address before the Royal College of Surgeons states that chemically induced tumors make their appearance after a much longer time than tumors induced by viruses. Yet in the same address it is said that the domestic rabbit strain of the Shope virus in domestic rabbits produces papillomas, nearly all of which become malignant within two years. It is stated furthermore that chemically induced tumors are confined to the site of application of the chemical. The production of tumors by chemicals in tissues distant from the site of application is ignored. The important observation of Rous and Kidd of the production of fulminating carcinosis at the site of the application of coal

tar to the skin of rabbits which are subsequently infected intravenously with the Shope virus, is again interpreted as showing that the tar merely prepares the ground for the action of the virus. This may be true, but is by no means proven. Both coal tar and Shope virus applied singly to the rabbits produce skin cancers after a long time. Is it so unreasonable, therefore, to assume that the action of the combination tar-virus may result in a summation or synergistic effect as evidenced by the shortening in the latent period for tumor production? Would a similar effect be obtained by the use of a non-carcinogenic tar or non-carcinogenic hydrocarbons in combination with the virus? How can the virus hypothesis explain the fact that the mere addition to, or elimination of a methyl group from, the ring structure of some hydrocarbons elicits or abolishes carcinogenic activity? Why are brain tumors found so seldom in the thousands of mice which have been kept under observation for long periods in cancer research laboratories (Slye, Holmes and Wells), while through the use of a few dozen mice such tumors have been induced chemically.

In short, it seems wiser for the present to admit our ignorance concerning the mode of action of carcinogenic agents, whether chemicals or viruses, in order to avoid unjustifiable generalizations. Speculations of course have their value, but this difficult problem will only be solved by further experimental work.

#### CHEMICAL CHARACTERISTICS OF TUMORS

A cardinal feature of all cancer cells is their progressive and apparently unrestrained proliferation in the animal body. It is pertinent, therefore, to inquire whether this peculiar behavior of malignant cells can be explained on a chemical basis. Here we meet at once with difficulties. In fact, the great amount of work done on this problem has rather emphasized the chemical similarity of malignant cells and the normal cells from which they arise. So far there has not been discovered a single qualitative difference in chemical composition. On the contrary, such highly specialized chemical functions as the production of specific hormones are retained by malignant tumors derived from hormone-producing glands. Whatever apparent chemical differences do exist are of a quantitative nature, and even in this regard there are exceptions to the rule. For instance, the well-known studies of Warburg on tumor tissue *in vitro* were supposed to distinguish malignant from normal tissues by the abnormally high aerobic glycolysis and defective respiration of tumor tissue. Cori and Warburg were able to show that venous blood from cancerous tissue contains more lactic acid and less glucose than other venous blood. We have extended these findings by showing that the lactic acid production of tumors in living animals fol-

lowing the intraperitoneal injection of glucose, fructose or maltose is sufficient to cause a striking decrease in the pH of the tumor, as measured by the capillary glass electrode. Under the same conditions the pH of such normal tissues as striated muscle and subcutaneous tissue was not changed. It is conceivable that the excessive amounts of lactic acid present in tumors, with the consequent decrease in pH, may be a factor favoring the necrosis of poorly vascularized parts of tumors, and is concerned in the destructive action of tumor cells on adjoining normal tissue.

In further work we have made some interesting observations on the relation of protein metabolism to tumor growth. It is obvious that the growth of malignant as well as normal tissues requires the synthesis of tissue proteins. The problem was attacked by a systematic study of the action of cathepsin in extracts of tumors and normal tissues. We found that the lytic activity of this enzyme is favored by anaerobic conditions. If, after a few hours of anaerobic digestion, the digests are oxygenated, the amino nitrogen decreases and the trichloroacetic acid precipitable fraction increases by about 30 per cent. This we interpret as evidence of a reversal of proteolysis or protein synthesis. This synthesis is accompanied by a progressive decrease in the concentration of reducing substances in the deproteinized fraction, as indicated by a decrease in the iodine titer. The importance of pH in this process is shown by the fact that protein synthesis is obtained only in the physiological pH range. Subsequent results by other workers, especially Bergmann's results with papain, have confirmed and extended our observations. We therefore suggested that the lytic and synthetic activity of cathepsin is regulated *in vivo* by the oxygen tension, pH and apparent oxidation-reduction potential in the tissues. Further evidence supporting this view has been obtained by Reiss, who, using electrometric measurements, found that the synthetic function of papain is favored by a positive potential, established by the addition of various oxidizing agents. As to the bearing of these results on the problem of cell proliferation, it is interesting to note that Havard and Kendall, working with tissue cultures in which the oxidation-reduction potential was set at different levels by the addition of redox indicators, found that a low potential, *i.e.*,  $E_h - 20$  to  $-30$  m.v. stops all mitosis. Several years ago Warburg reported that exposure of tumor animals to low atmospheric oxygen tensions caused wide-spread tumor necrosis, and Campbell and Cramer observed a considerable decrease in the tumor growth rate.

We have also studied another phase of the problem of the relation of proteins to tumor growth. Classical nutrition experiments have shown that the growth rate of young animals, and therefore tissue proliferation,

does not proceed normally unless the diet contains an adequate amount of so-called essential amino acids. It is of considerable interest, therefore, to ascertain whether or not tumor growth is also inhibited by diets deficient in certain amino acids. The special diets were fed to female mice with small spontaneous mammary cancers. The growth-promoting properties of each diet used were carefully studied on young normal mice. Without going into details it was found that two different diets deficient in lysine caused a striking inhibition in tumor growth. The subsequent addition of lysine to the diet resulted in a prompt increase in the rate of tumor growth.

Experiments with a zein diet, supplemented with lysine, also caused a marked retardation of tumor growth. In this case the addition of tryptophane to the diet did result in a pronounced growth stimulation of the tumors.

Further experiments showed that a diet containing 17 per cent. of dried whole milk powder as the sole source of protein was inadequate for the growth of young mice or for tumor growth. However, when this diet was supplemented with 0.4 to 0.6 per cent. of cystine the young mice grew normally and the growth rate of the tumors was greatly increased. A striking stimulation of tumor proliferation was also obtained when tumor mice on the basal diet received daily subcutaneous injections of glutathione.

Since supplementing the basal diet by methionine has failed consistently to stimulate tumor growth, it would appear that under the conditions used cystine, as such, or in the form of glutathione, is a more powerful stimulating factor than methionine. In this connection reference may be made to the recent important studies of Rose and his coworkers. They find that normal rats lose weight and die if fed on a diet containing an abundant amount of cystine, but no methionine. On the other hand, the animals grow when the diet contains an adequate quantity of methionine but no cystine. Therefore, methionine, but not cystine, is considered an "essential" amino acid. However, if methionine is fed at a level which permits only slow growth the addition of cystine greatly increases the growth rate. If it be permissible to apply to mice the results obtained with rats, it would follow that the basal diet used in our experiments supplied only sub-optimal quantities of methionine, and, therefore, the administration of cystine or glutathione stimulated tumor growth. Further experiments on the relation of methionine to tumor growth are in progress.

One important function of the amino acids is to furnish the building stones for the construction of tissue proteins. Evidence is also slowly accumulating which indicates that amino acids possess some other specific biological functions in the proliferation and differentiation of cells and in the synthesis and activi-

ties of enzymes. The stimulating action of glutathione on tumor growth may be explained on this basis, since Hammett, and Voegtlin and Chalkley have shown that under certain conditions glutathione stimulates the division of normal cells by accelerating the growth rate of the cell nucleus.

#### CHEMICAL TREATMENT OF CANCER

The limitations of the surgical and radiation treatment of cancer have encouraged efforts to discover chemical therapeutic agents. For instance, Murphy postulates that tissue growth is controlled by stimulating and inhibiting substances of an unknown chemical nature. It is significant that he and his coworkers found that repeated intraperitoneal injections of extracts derived from placenta or embryo skin into mice with spontaneous mammary cancer arrested tumor growth in about 70 per cent. of the animals, and in 22 per cent. the tumors actually regressed. These changes were accompanied with a marked reduction or absence of mitotic figures in the tumor tissue. More recently they found that a potent inhibiting fraction could be isolated from the mammary tissue of the cow and rabbit in the prelactating or early lactating stage.

During the last few years new interest has been aroused in the apparently selective action of certain bacterial toxins. Workers in the Public Health Service have been engaged in attempts to isolate active fractions from certain bacterial filtrates. Such fractions isolated from filtrates of *B. prodigiosus* grown on a synthetic medium, when injected into mice with rapidly growing transplanted sarcomas, cause severe hemorrhages in the tumors and many of the growths regress. This action is apparently due to rupture of the fragile, newly formed blood capillaries in rapidly growing tumors.

The old gout remedy colchicine, a phenanthrene derivative, is known to arrest mitosis, and suggestive results have been obtained, indicating that the growth of certain mouse tumors can be inhibited by this drug.

Quite recently Strong reported extensive liquefaction and complete regression of spontaneous mammary cancer in mice following oral treatment with heptyl-aldehyd.

Experiments are also in progress in several laboratories designed to discover artificial radioactive substances with a selective action on tumor tissue. Success in these efforts, I believe, will largely depend on the selective distribution of the substances in malignant tissue. It is possible that radioactive iodine may perhaps be useful in the treatment of neoplasia of the thyroid.

Hammett and Reimann have observed an inhibiting effect of cystine disulfoxide on the growth of mammary cancer in mice. We have carried out well-controlled experiments with a series of synthetic aromatic sulfur

compounds and find that some of these have a definite inhibiting action on the growth rate of spontaneous mammary cancer in mice.

This survey of the experimental chemical treatment of tumors is merely intended to demonstrate that at least some suggestive results have been secured in this field. In view of the quite unexpected recent development of the chemotherapy of bacterial diseases it may not be over-optimistic to look forward to the time when similar results can be achieved in the chemical treatment of neoplasia.

In conclusion I hope that I have shown that encouraging progress has been made in the study of certain chemical aspects of cancer. There is every reason for looking forward confidently to the rapid accumulation of new knowledge, which will be helpful in the gradual solution of this important and baffling problem. It is most gratifying that the establishment of several well-endowed cancer research foundations and the recent creation of the National Cancer Institute have furnished the means for a concerted scientific attack on this devastating disease.

## OBITUARY

### DR. FRED BAKER

WITH the death of Dr. Baker, of San Diego, Calif., on May 16, 1938, a life of a very exceptional combination of valuable human qualities came to an end. Medical practice, specialized on eye, ear, nose and throat, was his sole means of livelihood and with his wife, also a physician, yielded a good family income.

Born at Norwalk, Ohio, on January 29, 1854, from early boyhood to the very end Baker's love of natural history was one of his foremost traits. Even his undergraduate course at Cornell was interrupted by extensive trips in Europe and Latin America, through all of which his broad naturalist proclivities were strongly to the fore.

Following graduation in medicine at the University of Michigan by him and his soon-to-be wife during the early eighties, after several thrilling experiences they found themselves (1888) in San Diego where, known to the community as Dr. Fred and Dr. Charlotte, their notable careers began at once. Being here chiefly concerned with Dr. Fred as a scientist, about him as a physician nothing need be said beyond reference to the extent to which he was recognized officially and otherwise by the profession of his city, county and state.

His contributions to natural knowledge as a researcher were limited to the mollusca, mainly as a conchologist. In this field he is widely known for his addition to knowledge of the marine fauna of Pacific North America; but still more probably to that of Brazil. His large paper on the last contained not only the descriptions of many new species, but important information on distribution and other ecological matters owing to his having done most of the collecting himself.

Up to near the end he was occupied, in collaboration with J. R. Le B. Tomlin, of the British Museum, on an extensive paper on Brazilian mollusca.

But a full account of his publications in this and other fields would be far from an adequate exhibit of

his contributions to science. As a collector (and this for him meant an explorer) his record is surprising. Thus from his own biographical notes: "On all their travels the Bakers have collected extensively specimens in conchology, botany and ichthyology, which have been given to the National Museum at Washington, the California Academy of Sciences in San Francisco, the Academy of Natural Sciences in Philadelphia, the University of California at Berkeley, and its Scripps Institution of Oceanography at La Jolla, and finally to the San Diego Museum of Natural History goes his own great working collection of shells."

His activities in connection with the Society of Natural History of San Diego were so extended in time and so efficient that it is hardly possible to speak of the institute apart from him.

But of all his efforts in behalf of institutionalized science, he regarded his part in the founding and operating of what is now the Institution of Oceanography at La Jolla, a branch of the University of California, as the most important. And surely no one who has had a hand in that enterprise can hesitate for a moment to acknowledge his service in that connection.

Finally a few sentences on his ideas and acts in the realm of civics. His years of service on the city council and the board of education—part of the time as president of both—and on the board of the then State Normal School at San Diego must suffice except for this one remark: Although never, so far as I recall, did I hear him say anything of the sort I am sure that in all these varied relations and activities he maintained much of the scientific attitude especially as this appertains to natural history. Whether as a physician dealing with defective vision of a patient; or as a member of boards dealing with the affairs of the Society of Natural History, or of the Institution of Marine Biology; or as a member of the city council dealing with the water problem; or as a member of the board of education dealing with the question of the presidency of the board, I am sure his youthful in-

terest in, and life-long devotion to, natural history were potent factors in it all.

A fitting close to this note may be a statement, which, though actually made by Dr. Charlotte in connection with the celebration of their golden wedding, was as truly expressive of his views as hers. "At heart," she said, "I am a politician. I am sorry to see that the meaning of that term has been corrupted until it is in disrepute. Actually it should be a fine thing to take an active interest in politics. It has always been a hobby of mine." This by a woman who was mother of two fine children and as a physician had helped more than a thousand mothers to bring children into the world without the loss of a single one of that host of mothers.

WILLIAM E. RITTER

UNIVERSITY OF CALIFORNIA

### LEE BARKER WALTON

WHEN on May 15, 1937, Lee Barker Walton was suddenly stricken there passed from the group of scientific workers in Ohio and throughout the country a figure not only prominent as an original investigator and science teacher but a man of striking personality and activity, beloved by a wide circle of intimate friends and associates.

Born at Bear Lake, Pa., November 12, 1871, he entered Cornell University and took his bachelor's degree there in 1897. Later he spent the years 1898 and 1899 in Germany—except for six months in India where, according to Mrs. Walton, "he was interested mostly in collecting butterflies and beetles." We may question this, since Caroline Louise Graham, the daughter of a missionary to India, later became Mrs. Walton. He went to Brown University in 1899 and served as assistant to Dr. A. S. Packard in 1900–1901, while working for the Ph.D. degree. He studied at Woods Hole during the summer of 1901 and was assistant to Dr. Bumpus at the American Museum of Natural History in 1901 and 1902. He was Goldwin Smith fellow and secured his Ph.D. at Cornell University in 1902 and that fall began his notable career at Kenyon College, Gambier, Ohio, where he remained an outstanding figure until his untimely death. In this position he at once identified himself with the Ohio Academy of Science and became one of its most loyal members, serving as secretary, president and on various principal committees. He served on the staff of the Lake Laboratory during the summers of 1905, 1906, 1907 and 1909, and was one of a group, mainly in the Ohio Academy of Science, which secured the organization of the Ohio Biological Survey as a department of the university, with a number of cooperating colleges in the state. He served as a member of the summer staff of the survey at various times, and in

this connection contributed two of his most important papers, "The Euglenoidina of Ohio" and "Studies Concerning Organisms Occurring in Water Supplies."

He was a member of a number of national scientific societies, among them the American Society of Zoologists, the American Society of Naturalists and the Entomological Society of America, and he was a fellow of the American Association for the Advancement of Science and a member of the council, from 1915 to 1917.

His interests were varied—not confined to his biological work—and he was particularly interested in outdoor sports for young men, tennis, golf, hiking, fishing, and said "more of that kind of interest would tend to keep the young men in the proper condition morally as well as physically." He was "a great believer in play as well as work."

He was interested in problems of evolution, and many of his published papers had a bearing upon various phases of these fundamental biological questions. He studied the phenomena of spiral movement in aquatic organisms as exhibited in regions north and south of the equator and the intricate structure of various arthropod groups to elucidate their phylogenetic affinities.

He was a successful teacher beloved by his students, many of them going on to successful careers, perhaps his greatest contribution to science and society. The writer thinks of him first as an admired companion whose friendship through the years is one of the treasured memories of life.

HERBERT OSBORN

### RECENT DEATHS

DR. FREDERICK PETERSON, from 1903 to 1915 clinical professor of psychiatry at Columbia University, died on July 9 at the age of seventy-nine years.

THE death in his fifty-sixth year is announced of Dr. F. P. Chillingworth, professor emeritus of pharmacology of the Tufts Medical School.

GEORGE W. CAVANAUGH, professor emeritus of chemistry at Cornell University, died on July 2, two days after his retirement from active teaching. He was sixty-eight years of age.

DR. JAMES LAWRENCE KELLOGG, professor emeritus of biology at Williams College, died on July 8. He was seventy-one years old.

DR. HOMER GAGE, consulting surgeon of Worcester, Mass., died on July 10, in his seventy-seventh year.

DR. A. GALT, keeper of the technological department of the Royal Scottish Museum, Edinburgh, from 1901 to 1920, died on June 26 at the age of eighty-three years.

## SCIENTIFIC EVENTS

### CANADIAN FIELD EXPEDITIONS

THE official announcement of the Mines and Geology Branch of the Department of Mines and Resources, Ottawa, states that the summer work of the National Museum of Canada will include biological and botanical investigations to be carried on in British Columbia, Alberta, Manitoba and Ontario, with archeological studies in Ontario.

The work is being directed toward the gathering of new information on Canadian fauna, flora and native races, and the acquiring of new specimens for the museum. R. M. Anderson, chief of the division of biology, is studying mammals in the Waterton Lakes district of Alberta; H. M. Laing is continuing a biological survey of the coast of British Columbia, with particular reference this year to the area in the vicinity of Bella Coola; Angus Shortt is continuing a study of bird life in Manitoba which is being carried out from Churchill southward to the International boundary. Work this year will be chiefly in the vicinity of Dauphin; R. C. Hosie is continuing with his botanical studies of the region north of Lake Superior, and W. J. Wintemberg will make excavations in the vicinity of Waubaushene on what may prove to be the site of an old fort of historic interest.

Fifty-eight survey and exploratory parties, comprising a force of nearly three hundred men, have been assigned to field work this year by the Mines and Geology Branch of the Department of Mines and Resources. The parties, most of which have already left Ottawa, will map and investigate areas in every mineral producing province in the Dominion and in Yukon and the Northwest Territories.

There are forty-one parties engaged in geological investigations and seventeen in topographical mapping. Of the former, nine are in British Columbia, two in Alberta, four in Saskatchewan, five in Manitoba, four in Ontario, six in Quebec, three each in New Brunswick and Nova Scotia, two in Yukon and one in the Northwest Territories. In addition to these, one party is engaged in the collection of mineral specimens in eastern Canada.

Three of the seventeen topographical parties have been assigned to British Columbia, four to Alberta, one to Saskatchewan, three to Quebec, one to Nova Scotia and three to the Northwest Territories. One party is engaged in physiographic studies in the eastern Arctic.

### MARINE STUDIOS

MARINE STUDIOS, a project comprising what is said to be the largest aquarium in the world and the only specially designed under-water motion picture studio, was opened to the public on June 23 at Marineland, eighteen miles south of St. Augustine.

This undertaking is the outcome of the efforts of W. Douglas Burden, associate curator and trustee of the American Museum of Natural History in New York, and his associates to portray the undersea world in natural surroundings, so that sea life under conditions as nearly identical as possible with those in which it exists in its natural state might be observed and photographed. In carrying out this plan Mr. Burden has had the cooperation of Ilia A. Tolstoy, grandson of Leo Tolstoy, the Russian writer, Miss Lillian Koehler, and their associates who have worked together from the beginning.

The undertaking revolves largely around the construction of the aquarium itself. Instead of the usual method of presentation whereby each species is segregated in its own small compartment, two large tanks present a facsimile reproduction of submarine life with each species playing the same part that it does in the ocean.

One tank is rectangular, 100 feet long, 50 feet wide and 18 feet deep; the other is circular, 75 feet in diameter and 11 feet deep. Enclosed galleries are built around each tank with observation platforms at different levels from which the public may view the spectacle of undersea life through more than 200 portholes built into the side of the tanks. The tanks and portholes were designed under the direction of a motion-picture engineer, who worked out in advance the various camera angles necessary to afford the greatest latitude in the filming of scenes.

The aquarium has been stocked with thousands of specimens, some rare in captivity. Two porpoises, a mother and her offspring, weighing probably 850 and 150 pounds, respectively, are believed to be the only two in the world in captivity; while two sawfish, one of which weighs over 1,000 pounds and is 14 feet, 8½ inches long, are the two largest in captivity. Other interesting specimens include five penguins imported from South Africa and South America, two large loggerhead turtles, numerous large sharks, rays, catfish, shrimp and thousands of coral and reef fish from off the Keys.

The formal opening ceremonies were conducted by Walter B. Frazer, mayor of St. Augustine, as master of ceremonies, with U. S. Senator Claude Pepper, Frank V. B. Couch, mayor of Daytona Beach; C. V. Whitney, and W. Douglas Burden participating.

### THE MOUNTAIN LAKE BIOLOGICAL STATION

THE Mountain Lake Biological Station of the University of Virginia opened on June 20 for its ninth session. Instruction is given in two terms of five weeks each.

The following courses are offered in 1938. In the first term Professor L. L. Woodruff, of Yale University, assisted by Samuel L. Meyer, will give instruction in protozoology. Bio-geology will be taught by Professor Joseph K. Roberts, of the University of Virginia. Professor C. E. McClung, of the University of Pennsylvania, will give a series of lectures entitled "One Hundred Years of the Cell Theory."

In the botanical field a course in the morphology of seed plants will be given by Ivey F. Lewis, director of the station and Miller professor of biology at the University of Virginia. Assistant Professor John M. Fogg, Jr., of the University of Pennsylvania, will continue the course begun in 1937 on the taxonomy of plants.

In the second term the zoological courses are: Morphology of the Animal Cell, by Professor Bruce D. Reynolds, of the University of Virginia, and the Biology of Vertebrates, by Maurice G. Brooks, of West Virginia University. Morphology of Pteridophytes will be handled by Major Robert P. Carroll, of the Virginia Military Institute, while Professor Robert F. Smart, of the University of Richmond, will offer work in mycology.

The emphasis throughout is on the living organism. As far as possible, material for dissection and experiment is collected by the students themselves with a view to avoiding the "glacial period" biology imposed of climatic necessity on students in the winter sessions of our colleges. For field work a wide variety of habitats is offered. The neighboring high dry ridges of the Alleghanies, the deciduous forests of the mountain slopes, the lake and mountain streams, cranberry bogs, the flood plain and bluffs of the New River give an altitudinal range from 4,500 to 2,000 feet.

The station buildings number nineteen, mostly small residential cottages of simple but comfortable construction along with the laboratory, the library and the dining-hall. The various buildings are named for biologists from the Southern States: Banister, Clayton, Elliott, Schweinitz, Audubon, Rafinesque, Michaux, Hentz, LeConte, Mohr, Gattinger, Catesby, Chapman, Walter Reed. The power lines of the Appalachian Power Company furnish dependable electric current to all buildings. Water from a spring high above the station is piped by gravity to the cottages.

Students and investigators come mostly from the South, though the station is open to those from elsewhere. Elaborate equipment for physiological work is not available, but the usual conveniences are offered for morphological or cytological investigations. Microscopes, microtomes, embedding ovens, centrifuge, glassware and the usual chemicals are at hand.

The library building is convenient, with study rooms available, but the supply of books is limited to the standard volumes bearing on the content of the courses given and some reprints. A complete file of

*Biological Abstracts* is on the shelves, and volumes wanted are obtained on interlibrary loans.

The climate of Mountain Lake is delightful. The thermometer seldom rises above 85 during the day, and the nights are uniformly cool. Field work is facilitated by the absence of insects and other pests that so often make collecting a grim test of fortitude. There are no mosquitoes, ticks, chiggers or poison ivy, though an occasional rattlesnake provides excitement for the uninitiated.

I. F. L.

### THE AMERICAN PUBLIC HEALTH ASSOCIATION

THE preliminary program of the scientific sessions of the sixty-seventh annual meeting of the American Public Health Association has been issued. The meeting will be held in Kansas City, Mo., from October 25 to 28. An attendance of 3,000 professional public health workers is expected.

Fifty morning and afternoon meetings have been arranged by the ten sections of the association. These are: Health Officers, Laboratory, Vital Statistics, Public Health Engineering, Industrial Hygiene, Food and Nutrition, Child Hygiene, Public Health Education, Public Health Nursing, Epidemiology.

Special sessions are planned on public health aspects of medical care, oral hygiene, professional education and diphtheria immunization. A public meeting under the auspices of the local committee is planned for Wednesday evening, October 26, when Dr. E. V. McCollum will discuss the pasteurization of milk and Dr. Arthur T. McCormack will speak on the new responsibilities of the health officer.

There will be symposia on industrial hygiene administration, venereal disease control, laboratory diagnostic methods, expanding responsibilities in public health engineering, maternal and child health, frozen desserts, industrial hazards, water and sewage, typhoid fever, the next steps in school health services, milk and dairy products and many other important subjects.

Among those who will take part in the program are: Colonel A. Parker Hitchens, Dr. Earle G. Brown, Dr. Haven Emerson, Surgeon-General Thomas Parran, Joel I. Connolly, Dr. Nina Simmonds, Dr. Karl F. Meyer, Dr. Walter Clarke, Professor C.-E. A. Winslow, Dr. George C. Ruhland, Dr. William A. Sawyer, Dr. Walter H. Eddy, Dr. Frank G. Boudreau, Sol Pineus, Dr. Martha M. Eliot, Dr. Abel Wolman, Dr. Robert S. Breed and Dr. Felix J. Underwood. More than 300 papers and committee reports will be presented during the meeting.

The preliminary program is published in full in the August issue of the *American Journal of Public Health*, published by the American Public Health Association, New York, N. Y.

## SCIENTIFIC NOTES AND NEWS

THE Colorado School of Mines at Golden conferred at commencement an honorary degree of doctor of philosophy on Dr. Victor C. Alderson. The degree was in the form of a diploma engraved upon a solid silver plate and encased in hand-tooled leather. Dr. Alderson was president of the school from 1903 to 1913, and from 1917 to 1924.

THE degree of doctor of pharmacy was conferred at commencement by the Philadelphia College of Pharmacy and Science on George W. Merck, president of Merck and Company, Rahway, N. J., and on Dr. Arno Viehoveer, research professor of biology and biochemistry at the college.

ROGER WILLIAMS, chemical director of the ammonia department of E. I. du Pont de Nemours and Company, received the honorary degree of doctor of science at the commencement exercises of West Virginia University, "in recognition of his distinguished services in chemical research, particularly in the field of high pressure synthesis leading to the commercial processes now so prominent in West Virginia's industrial community."

THE honorary degree of doctor of science will be conferred by the University of Oxford on July 30 on Dr. Charles Gustave Jung, professor of psychology at Zurich.

AN oil painting of Dr. James Carroll Flippin, dean and professor of internal medicine at the University of Virginia, has been presented to the university by the alumni and graduating class of 1938. The university conferred on him the honorary degree of doctor of science at its commencement exercises.

AT Tulane University, plaques commemorating the retirement of William B. Gregory, professor of experimental engineering and hydraulics, for forty-four years a member of the faculty, and of Herman F. Hustedt, a member of the faculty for fifty-four years in the department of mechanic arts, were presented to the college by members of the senior engineering class on June 16. They will be hung in the engineering building.

DR. WILBER DWIGHT ENGLE, emeritus vice-chancellor and professor of chemistry of the University of Denver, was at commencement presented with a "Memory Book," containing letters of appreciation from faculty members, friends and former students, and also a "Memorial Chair" in the Central City Opera House. Dr. Engle served the university as teacher, dean, vice-chancellor and on two occasions as acting chancellor, from 1894 to 1937, when he retired.

Nature reports that Dr. C. Thurstan Holland, of

Liverpool; Professors R. Keinböck, of Vienna; Holt-husen of Hamburg; Hans Meyer, of Bremen; Perussia, of Milan; De Quervain, of Bern, and Regaud, of Paris, were elected to honorary membership in the Swiss Röntgen Society, on the occasion of the twenty-fifth anniversary of the society.

SIR ALDO CASTELLANI, head of the department of tropical medicine at the Louisiana State University, has been elected an honorary member of the Hanseatic University of Hamburg.

THE Society for the Promotion of Engineering Education on June 29 presented the Lamme Medal for achievement to Robert Lemuel Sackett, dean of the School of Engineering at the Pennsylvania State College from 1915 to 1937, in recognition of "his work in coordinating the thought of industry and education for the improvement of their understanding of their mutual problem in selecting and developing potential leaders." Dr. S. B. Earle, president of the society and dean of engineering at Clemson Agricultural College, made the presentation at the annual dinner. George B. Thomas, personnel director of the Bell Telephone Laboratories, made the citation.

THE College of Physicians of Philadelphia awarded on July 14 the Alvarenga Prize to Dr. Richard E. Shope, of the Rockefeller Institute for Medical Research, Princeton, N. J., for his recent researches on the etiology and epidemiology of influenza. This prize was established by the will of Pedro Francisco deCosta Alvarenga, of Lisbon, an associate fellow of the College of Physicians, "to be awarded annually on each anniversary of the death of the testator on July 14, 1883, to the author of the best unpublished essay upon any branch of medicine deemed worthy of the prize."

THE fiftieth anniversary of the election to the Academy of Medicine, Paris, of M. A. d'Arsonval, of the University of Paris, who is now eighty-seven years old, was celebrated on June 7 by the presentation to him of a medal by the academy. At the close of an address made by Professor Fernand Bezançon, president of the academy, M. d'Arsonval spoke in acknowledgment for half an hour.

OFFICERS of the American Medical Association were elected at the San Francisco meeting as follows: *President-elect*, Dr. Rock Sleyster, Wauwatosa, Wis.; *Vice-president*, Dr. Howard Morrow, San Francisco. Dr. Olin West, Chicago, was reelected *secretary*. The convention in 1939 will be held in St. Louis, in 1940 in New York City and in 1941 in Cleveland.

THE following officers were elected at the annual meeting on June 10 in San Francisco of the American

Society of Clinical Pathologists: *President-elect*, Dr. L. W. Larson, Bismarek, N. Dak.; *Vice-president*, Dr. W. Cummins, San Francisco; *Executive Committee*, Dr. C. W. Maynard, Pueblo, Colo., Dr. O. W. Lohr, Saginaw, Mich.; *Board of Registry*, Dr. P. Hillkowitz, Denver, Dr. K. Ikeda, St. Paul; *Board of Censors*, Dr. W. S. Thomas, Clifton Springs, N. Y., Dr. I. A. Nelson, Tulsa, Okla. Dr. B. T. Terry, of Tacoma, Washington, was awarded the gold medal for his exhibit "Aids in the Rapid Diagnosis of Tissues." Dr. T. B. Magath, Rochester, Minnesota, is president for the coming year.

DR. MARCUS STULTS FARR, associate professor of geology and paleontology at Princeton University, retires this year from active teaching. He joined the faculty of the university in 1896. Since then he has served the university continuously, except for two years, from 1898 to 1900, when he was assistant zoologist in the New York State Museum at Albany.

DR. JOHN A. GOFF, professor of thermodynamics at the University of Illinois and a consultant for the Westinghouse Research Laboratories, has been appointed dean of the Towne Scientific School of the University of Pennsylvania. He also will hold the Whitney professorship of dynamical engineering. He succeeds the late Dr. Robert H. Fernald.

F. ELLIS JOHNSON, dean of the college of engineering at the University of Missouri, has been appointed dean of the College of Engineering at the University of Wisconsin.

AT Yale University, Dr. Lorande Loss Woodruff, professor of protozoology, has been appointed chairman of the department of zoology and director of the Osborn Zoological Laboratory.

RECENT appointments to the faculty of the Peiping Union Medical College are Dr. Otto Kraye, associate professor of pharmacology at the Harvard Medical School, to the chair of pharmacology, beginning in September, 1939, and Dr. Frank E. Whitacre, assistant professor in obstetrics at the University of Chicago, to the chair of obstetrics and gynecology, beginning in January, 1939.

PROFESSOR J. IRVINE MASSON has been elected to the office of vice-chancellor of the University of Sheffield, which is about to become vacant owing to the retirement of Dr. A. W. Pickard-Cambridge. Professor Masson holds the chair of chemistry and is head of the department of pure science in the University of Durham.

SIR WILLIAM WRIGHT SMITH, regius keeper of the Royal Botanic Garden, Edinburgh, has been named to the honorary professorship of botany of the Royal Horticultural Society in the place of the late Dr. A. B. Rendle.

THE council of the British National Institute of Agricultural Botany has appointed M. A. Bailey, director of research to the Government of Sudan, director of the institute in succession to the late W. H. Parker.

*The Museum News* states that Dr. Wendell C. Bennett, assistant curator of anthropology of the American Museum of Natural History, has been appointed field curator for the Pacific Basin exhibit of the Golden Gate International Exposition, San Francisco. He is working this month at Lima, Peru, assembling the Peruvian exhibition for the exposition.

DR. WILLIAM EWART LAWRENCE, assistant professor of sociology at Western Reserve University, has been granted leave of absence for the semester beginning in September to go to Yale University to make a cross-cultural survey of the primitive tribes of Australia for the Institute of Human Relations in cooperation with the Rockefeller Foundation. The study will be organized under Professor George P. Murdock, director of the Institute of Human Relations.

DR. FRANZ HABER, who during the war developed methods of extracting nitrogen from the air for producing explosives, has taken up his residence in England.

DR. CHAUNCEY D. LEAKE, professor of pharmacology at the University of California, gave a Mayo Foundation lecture at the Mayo Clinic, Rochester, Minn., on June 6 on "Pharmacologic Aspects of Central Nervous System Activity."

LEADING workers in the study of cosmic rays met at the University of Chicago on June 28 and 29 for an informal exchange of recent experimental data and for discussion of new theories about the nature of the rays made necessary by the new evidence. Professor Arthur H. Compton, of the University of Chicago; Dr. M. S. Vallarta, of the Massachusetts Institute of Technology; Dr. T. H. Johnson and Dr. W. F. G. Swann, of the Bartol Research Foundation; Professor J. C. Street, of Harvard University, and Professors W. M. Nielsen and L. W. Nordheim, of Duke University, presented papers at the symposium.

THE Illinois Society of Consulting Psychologists, now in its third year of existence, recently elected the following officers for the year 1938-1939: *President*, Dr. Arthur W. Kornhauser, of the University of Chicago; *Vice-president*, Dr. Andrew W. Brown, of the Institute for Juvenile Research, Chicago; and *Secretary-Treasurer*, Dr. Helen L. Koch, of the University of Chicago.

THE *London Times* reports that the British Universities Polar Expedition recently arrived at Leith in the Norwegian sealing vessel *Isbjohn*. The ten mem-

bers of the expedition were under the leadership of J. M. Wordie, of St. John's College, Cambridge, who sailed with Shackleton to the Arctic in 1914. The main purpose of the expedition was to study cosmic rays at high altitudes near the North Magnetic Pole. Six new fjords and several islands and bays on the north-east coast of Baffin Land, between Cape Bowen and Cape Antrobus, were discovered. A running survey of about 600 miles of new coastline was made in about a fortnight. Many ancient Eskimo settlements around Baffin Bay were excavated, throwing new light upon the origin of the Greenland Eskimo and the routes by which the Eskimo entered Greenland from Alaska and Baffin Land. The expedition has brought back what is said to be the finest representative series of Eskimo antiquities, and which will be deposited in the Cambridge Museum.

THE *London Times* also states that H. W. Tilman, who led the party which climbed Nanda Devi, will lead the British expedition to Mount Everest this year. Nanda Devi (25,645 feet) is the highest peak in the British Empire, and the highest yet climbed. Mr. Tilman was a member of the reconnaissance party in the 1935 Mount Everest expedition. Permission for the attempt has been granted by the Tibetan authorities.

SIR WILLIAM BRAGG, president of the Royal Society, on June 9 officially opened the Meyerstein Institute of Radio-Therapy at the Middlesex Hospital, London, when Sir Edward Meyerstein, who has already contributed £30,000 towards the cost of the institute, announced his intention of giving the remaining £16,000 necessary to defray the cost. The institute is a compact and complete unit in which all forms of radio-therapy are available for both in-patients and out-patients, whether hospital or private. It is closely linked to the main hospital. There are four floors devoted to treatment with radium and x-rays, while sixty-four hospital beds in four wards and six private-patient rooms house those in-patients receiving treatment under the care of the honorary physicians and surgeons of the hospital.

IN June, 1935, A. T. Marston was responsible for the discovery of a human occipital bone at a depth of 24 feet from the surface in the stratified Middle Gravels of the 100-foot terrace of the Thames at Swancombe, Kent. The following March he discovered a left parietal bone, which it is stated articulated perfectly with the occipital. A committee under the auspices of the institute has been formed to investigate the evidence which has been collected and to cooperate in the further exploration of the site. This committee consists of M. A. C. Hinton, keeper of zoology, British Museum, *chairman*; K. P. Oakley, department of

geology, British Museum, *secretary*; Professor P. G. H. Boswell, department of geology, Imperial College of Science; Professor W. E. Le Gros Clark, department of anatomy, University of Oxford; Dr. F. Corner; H. G. Dines, Geological Survey of Great Britain; C. F. C. Hawkes, department of British antiquities, British Museum; Professor W. B. R. King, department of geology, University College, London; A. T. Marston; Dr. G. M. Morant, Galton Laboratory, University College, London, and S. Hazzledine Warren. The committee is receiving financial support from the Royal Society.

AN extension of the Agricultural Economics Research Institute in Parks Road, Oxford, England, providing extra library accommodation and six extra rooms for research, as well as one for calculating machines, was opened by W. S. Morrison, Minister of Agriculture, on June 4. The *London Times* writes: "It was just a generation ago that the institute began, in one room. The next year, 1914, it moved to Broad Street, and in 1919 there was a big reconstruction, with a grant augmented to £4,000. There was another in 1932, when eight rooms were added to the Parks Road Accommodation, and the present extension, costing £1,750, will give adequate provision for the staff of twenty-six members, under the direction of C. S. Orwin." A review of the work of the institute was issued on the occasion of the twenty-fifth anniversary of its foundation.

ACCORDING to a summary of the Registrar General's Statistical Record of England and Wales for 1935, which was issued on February 6, the estimate of the population of England and Wales in the middle of 1935 was 40,645,000 persons, of whom 19,500,000 were males and 21,145,000 females. The total was 178,000 greater than the estimate for the previous year. The average ages of the population were 32.7 years for males and 34.5 for females. These are gradually increasing; in 1921 they were 29.9 and 31.2, respectively. The marriages registered during 1935 numbered 349,536, an increase of 7,229 compared with 1934. The number of divorcees in 1935 was 4,069, higher than in any previous year except 1934, and the number of divorced persons who remarried, 5,662, was a record. The live births registered in the year were 598,756, or 1,114 more than in 1934. The corresponding birth-rate was 14.7 per 1,000 population. A comparison with the rates in many other countries showed that only three of them—Austria, Norway and Sweden—had lower rates. The number of male births exceeded the number of female births in the ratio of 1,056 to 1,000. This ratio was approached in 1843 and 1844, when 1,054 was recorded, but it has only been exceeded once—in 1919, with a ratio of 1,060.

## DISCUSSION

**"RED WATER" ALONG THE WEST COAST OF THE UNITED STATES IN 1938<sup>1</sup>**

ALTHOUGH "red water" in many seas in widely separated parts of the world is a well-known natural phenomenon commented upon by explorers, oceanographers and travelers over a period of many decades (or even centuries) its occurrence has not been recorded very frequently in most localities. This is particularly true of the Pacific Coast of the United States, where not more than a score of occurrences have been recorded in a period of twenty years or more.

Those familiar with the origins and histories of outbreaks of "red water" know that the actual frequency of occurrences is not accurately represented by this rarity of reports, but in the present state of our knowledge of the sea it is impossible to say how far wrong inferences based on published reports may be. For one thing, it is fairly certain that many outbreaks of "red water" are so sharply limited in time and space that they fail to reach or to attract the attention of interested observers. For another thing, many occurrences of large abundances of organisms deserving to be listed as "red water" lack the strong and striking depth of discoloration which stimulates an observer to make the record.

Even an experienced observer may sail through an expanse of water showing a dingy chocolate or other inconspicuous color and think nothing of it, although the microscopic organisms causing the color may be present in numbers of a half million to a full million per liter of sea water at or near the surface. Yet the difference between that color and one of distinct redness may rest only on the presence of another million or two, a mere doubling or trebling of the less conspicuous density of population.

Within a period of three weeks I have had the unusual experience of seeing three separate and distinct occurrences of "red water" in or near sandy beaches of the East Pacific, facts which seem to be worth recording without delaying for extended discussion.

On May 14, 1938, I made a brief visit to Copalis Beach, located a little to the north of Gray's Harbor, Washington. There I found the water in and near the breakers colored a dingy, reddish brown by the presence in great numbers of the discoid diatom *Aulacodiscus kittoni* Arn. which has made the beach especially interesting to petroleum geologists<sup>2</sup> and to

certain marine biologists for a decade or more. On account of a strong breeze and rough sea, I could not tell how far to seaward the discoloration extended, but it was at least far enough to warrant the application of the term "red water" to the appearance of the immediate vicinity.

On May 15, at Seaside, Washington, on the "long beach" a few miles north of the Columbia River, I found a discoloration essentially similar to that at Copalis except that foam developed in the breakers and gave a much lighter shade of color. In this case, also, a strong breeze and rough sea prevented a view to seaward. The organism responsible for the color in that place was a plankton diatom, *Asterionella kariana* Grun, which had been observed in northern collections made for the Scripps Institution of Oceanography but never before in striking abundance.

Some time in the latter part of May the water in La Jolla Bay near the pier of the Scripps Institution began to show patches of discoloration. This condition attracted some comment but little other attention from members of the scientific staff of the institution until June 3, when certain patches became notably prominent. On that date I found in the densest patch an abundance of about 500,000 individuals per liter of *Gonyaulax polyedra* Stein, the dinoflagellate which had been held responsible for wholesale destruction of inshore animal life in the Southern California region in 1901.<sup>3</sup> The color was much like that observed at the two northern beaches, a dingy or muddy chocolate. About twenty species of other phytoplankton organisms were also present.

On June 6 an area distinctly red in color drifted into La Jolla Bay from the northwest at about noon. With the exception of a few thinner streaks, it covered an expanse of several square miles. On June 7 I was told by a pleasure fisherman that the "red water" had interfered with sport fishing near the Coronado Islands (off San Diego). If so, the region affected must have been at least twenty-five or thirty miles long and five to ten miles wide. At the point of strongest discoloration on June 6 near the institution pier, where the red was much like that of nearly fresh blood, the numbers of *Gonyaulax* specimens were about 3,000,000 per liter. This color was so conspicuous that it attracted the attention of nearly every one about the institution, yet its biologic and oceanographic significance may have been no greater than that of the less striking discoloration of June 3 or of a week earlier.

The experiences of an individual observer with these three occurrences is fairly indicative of the oppor-

<sup>1</sup> Contributions from the Scripps Institution of Oceanography. New Series, No. 21.

<sup>2</sup> P. D. Trask, "Origin and Environment of Source Sediments of Petroleum," Gulf Publishing Company, 1932.

<sup>3</sup> H. B. Torrey, *Amer. Nat.*, 36: 187-192, 1902.

tunities for drawing unsoundly extensive conclusions from non-extensive observations or from sporadic records of observations. For example, even though daily observations in La Jolla Bay for nearly twenty years have failed to reveal so many as ten occurrences of "red water," it is not scientifically safe, or permissible, to conclude that the number of occurrences in the Gulf of Catalina in that time have been restricted to that limit or anywhere near it. Even a question so simple as that of frequency of occurrence of a natural phenomenon like "red water" in a geographic region requires an indefinite number of positive records for a reliable answer.

W. E. ALLEN

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#### PARADICHLORBENZENE AS A CONTROL FOR BLUE MOLD DISEASE OF TOBACCO

BLUE mold (downy mildew) *Peronospora tabacina* Adam., has in recent years become a serious problem for tobacco growers in the United States. In 1935, a gas treatment for this disease was reported.<sup>1</sup> Extensive tests with the benzol-gas method in this country have shown that it is highly effective but probably too cumbersome and expensive to be generally practical under our conditions. Evaporating pans are scattered through the bed to be treated and must be filled nightly. These are inconvenient and likely to be overturned. Seeking a material that would be simpler to use, tests were initiated with paradichlorbenzene. Under greenhouse conditions, paradichlorbenzene vapors gave effective blue mold control and 1 ounce by weight of the crystals was equal in effectiveness to 5 fluid ounces of benzol. Plant bed studies were begun this spring, and experiments have now been completed by J. G. Gaines at the Coastal Plain Experiment Station, Tifton, Georgia, and W. M. Lunn at the Pee Dee Experiment Station, Florence, South Carolina. Paradichlorbenzene was used at the rate of 1 ounce to 4 or 5 square yards of bed area. Adequate control of blue mold was obtained, the results being fully equal to those secured in adjoining plots with standard benzol treatments. In these tests the full amount of paradichlorbenzene required for the area to be treated was weighed out and scattered on boards to evaporate. In one experiment a narrow shelf running inside and near the top of the sidewalls of a bed 9 feet wide gave adequate blue mold protection throughout the bed. Treated beds were enclosed nightly with the usual muslin sheeting to hold in the fumes. Obviously, more extensive tests under a wide variety of conditions must be conducted before final conclusions can be drawn. It does appear,

<sup>1</sup> H. R. Angell, A. V. Hill and J. M. Allen, *Jour. Coun. Sci. and Indust. Research, Aust.*, 8: 203-213, 1935.

however, that paradichlorbenzene as a substitute for liquid benzol may be a distinct advance toward making the gas treatment for blue mold disease simpler to use and hence more practical.

E. E. CLAYTON

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U. S. DEPARTMENT OF AGRICULTURE

#### TRANSMISSIBLE LYSINS IN WATER EXTRACTS OF SEEDS

LYSINS transmissible in series are generally recognized to be wide-spread in nature. They are found in decaying organic matter, such as manure, septic tanks, decaying vegetables, infected plants, degenerating nodules of legumes, sewage disposal beds, runoff water in creeks and rivers, and various other sources. So far as we are aware, however, water extracts of viable seeds have never been reported as a source of such substances.

The presence of a lytic factor for *Aplanobacter stewartii* (E. F. Smith) McCulloch was first detected in an investigation of the nature of the resistance of field corn to the bacterial wilt disease. Water extracts of the grain tested against the bacterial wilt organism revealed that there was a close correlation between the resistance of the variety to the wilt and the presence of a lytic factor in the seed. Resistant varieties of field and sweet corn generally contained the lytic factor; whereas susceptible varieties of sweet, flint and pop corn did not.

The investigation was further extended to include seeds of cereals and grasses. Tests were made of the seed of nineteen different species. Two strains of *Apl. stewartii* were used as test organisms, and very strong transmissible lytic factors were found to be present in water extracts of rye, oats, foxtail, winter wheat, redtop and timothy. Weaker lysins with respect to the test organisms were detected in alfalfa, red and alsike clover, but none in soybeans.

In order to determine the probable identity of the lysins in seeds with a bacteriophage isolated from a fire blight canker, the following points of comparison were considered: (1) transmission in series with increase in titer; (2) formation of plaques; (3) loss of pigment of the test organism in the secondary growth following initial lysis and inhibition; (4) thermo-inactivation temperature; (5) effect of dilution; (6) effect of certain organic reagents, such as acetone, ether, chloroform and alcohol; (7) adaptation of the seed lysin to organisms upon which at first the lytic factor had little or no effect.

Basing our conclusions upon these seven points of comparison, we can entertain little doubt but that the lysin of seed extracts is the same as the lytic factor found in fire blight canker. The slight variations noted were considered of little importance. The lysin in

some seeds was found to have a higher initial titer against one strain of *Apl. stewartii* than against another. In other cases, the same degree of lysis was demonstrated against both strains. In a few instances the extract contained a lysin effective against one strain only.

The lytic substance from seeds was usually not effective in as high a dilution as the lysin from fire blight canker. The latter had been in association with its test organism much longer than the former.

ROY C. THOMAS

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### GRAZING IN RELATION TO THE CONTROL OF LEAFY SPURGE

EXPERIMENTS conducted the past summer (1937) at this station have demonstrated that sheep will eat leafy spurge (*Euphorbia virgata* Wldst. and Kit.), and keep it under control. Two one acre plots were enclosed with woven wire and on July 2 four ewes and five lambs were confined on each plot. A similar lot of sheep was allowed to run at large in the pasture. The sheep used were of western origin and had been grazing a spurge infested pasture since early spring. The animals were weighed at the beginning of the experiment and at frequent intervals during the summer. Shelter, water and salt were provided. One plot was mowed and raked and the other left unmowed. The plots were in a pasture, the vegetation of which consisted chiefly of a mixture of spurge and bluegrass in a fairly uniform stand. Accurate counts indicated that there were on an average 370 stalks of spurge ranging from 12 to 30 inches tall and mostly in blossom

or forming seeds and 298 small clumps of blue grass per square meter.

On August 2 the sheep on the mowed plot were removed because of lack of forage. Weights taken on this lot indicated that the ewes had lost an average of 14.1 pounds (a not unusual loss of weight in ewes with lambs) and the lambs gained an average of 13.0 pounds.

On August 12 the sheep in the unmowed plot were given access to both plots until September 24. On this latter date the ewes had lost an average of 17.5 pounds and the lambs had gained an average of 28.5 pounds.

The sheep given the run of the regular pasture showed a gain of  $\frac{1}{4}$  pound per ewe and 26.25 pounds per lamb on September 24.

The experiment terminated on September 24 and at this time the spurge stalks were almost completely stripped of leaves, flowers and seeds. Practically no new growth of the weed was evident. The blue grass was also eaten off close to the ground.

The results reported above are at variance with these reported by other workers. Bakke,<sup>1</sup> in Iowa, reports little success with this method of control for spurge and states that according to Esser<sup>2</sup> this weed is poisonous to animals. In our trials the sheep ate the weed quite readily and in no case were any harmful effects noted.

Studies will be continued this summer in order to secure data on survival and the effect of grazing on root reserves. Further studies on the carrying capacity of the spurge will also be made.

E. A. HELGESON

E. J. THOMPSON

NORTH DAKOTA AGRICULTURAL  
EXPERIMENT STATION

## SCIENTIFIC BOOKS

### ORGANIC CHEMISTRY

*Organic Chemistry—An Advanced Treatise.* HENRY GILMAN, editor-in-chief, assisted by ROGER ADAMS, HOMER ADKINS, HANS T. CLARKE, CARL S. MARVEL and FRANK C. WHITMORE. 2 volumes, lvi + 1890 pp. John Wiley and Sons, New York, 1938. \$15.00. (Sold separately, \$7.50 per volume.)

TEXT-BOOKS often fall into a stereotyped pattern which persists for many years until some new author creates a new mold which in its turn becomes a model for later books. The traditional "organic chemistries" have for years been molded along quite similar lines. The present volumes are a sharp break from this tradition, and in that respect alone are almost unique in the text-book field.

These volumes comprise in reality a series of twenty-two short monographs bound together. There is no

essential interrelationship between most of the individual chapters. One chapter does not logically lead to another, but each is an entity in itself. This is necessitated by the fact that each chapter is written by a specialist, or by a small group of specialists, competent to speak with authority in that special field.

The work may be divided into three major subdivisions dealing respectively with the theory and nature of reactions in organic chemistry, the relationships between physical properties and the structural constitution of organic molecules, and a series of chapters dealing with some of the more important naturally occurring organic compounds. In the case of this latter group of chapters, the approach is largely from the standpoint of the organic chemistry which is involved so that these chapters tend to sup-

<sup>1</sup> A. L. Bakke, Ia. Ag. Exp. Sta. Res. Bull. 222, 1937.

<sup>2</sup> P. Esser, "Braunschweig." 1910.

plement but not to greatly duplicate the more biochemical treatments which are available in other monographs.

It is frankly a text-book for the advanced student, for one who already has a strong background of descriptive organic chemistry, and is designed for instruction at the graduate level. As such a text it merits and will unquestionably receive wide adoption. In many instances the material in a single chapter is nowhere else available in monograph form, so that from the standpoint of time-saving alone the student of theoretical organic chemistry should be enormously assisted by possessing these volumes. Furthermore the text gives every evidence of a careful sifting of the literature by one who has himself worked in that special field so that much of the dross has been sifted out in the process of compilation.

Volume I deals with organic theory and includes a consideration of Alkyl Compounds and the Theory of Strain; Theory of the Structure and Reactions of Aromatic Compounds; Stereoisomerism; Organometallic Compounds; Free Radicals; Unsaturation and Conjugation; Open-Chain Nitrogen Compounds; Molecular Rearrangements; and Comparison of Chemical Reactivity.

Volume II contains four chapters closely allied to those in Volume I, *i.e.*, Modern Electronic Concepts of Valence; Constitution and Physical Properties of Organic Compounds; Rotatory Dispersion; and The Significance of Resonance to the Nature of the Chemical Bond and the Structure of Molecules, and in addition nine chapters dealing with natural products, Natural Amino Acids; The Chemistry of Pyrimidines, Purines, and Nucleic Acids; Alkaloids; The Anthocyanins and the Flavones; Carotenoids: The Polyene Pigments of Plants and Animals; The Sterols, Bile Acids, and Related Compounds; and Chapters 16, 17, and 18 on the carbohydrates. As already noted, the approach of all of these natural-product chapters is that of the organic chemist, although there is considerable biochemistry and some biology interwoven into certain of the discussions.

The editorial board is to be congratulated on the high standard of excellence maintained for the individual chapters. The volumes are highly recommended for adoption as an advanced text. They should be on the study desk of every teacher of organic chemistry

and of every advanced student of chemistry. Even those whose interest lies wholly in physical chemistry will find here much that will interest them.

ROSS AIKEN GORTNER

UNIVERSITY OF MINNESOTA

### THE ORIGIN OF LIFE

*The Origin of Life.* By A. I. OPARIN. Translated by Sergius Morgulis. Macmillan, 1938.

IN this book a biochemist brings chemical evidence to bear on the subject of the origin of life. It is, of course, impossible for him to prove his theory; but taking into consideration several organic and physico-chemical facts, a well-knit story is told.

Without going into details, Professor Oparin is against any theory which is based on some "sudden" generation of life; nor is he more favorably disposed towards Schafer's conception that life-giving, organic substances are constantly being evolved from inorganic material. Nor, indeed, does the author feel that there is any absolute difference between the "lifeless" and the "living." He discards completely the conception of a "vital energy." At some dim and distant period in the history of the world, when a gaseous mass separated from the sun and became the earth, certain "matter" began gradually to evolve until a simple primary organism was formed. During such untold years carbides were transformed to hydrocarbons, the latter gave rise to alcohols, aldehydes and organic acids, and, in the presence of ammonia, to amides, and, in the presence of water, high molecular organic compounds, including proteins, appeared.

Colloids representing complex organic molecules were first uniformly distributed in solution; these then separated into "semi-liquid, colloidal gels" with an all-important spatial arrangement within their molecules. The colloids grew; and such "colloidal systems with a highly developed physico-chemical system" gave rise to the simplest primary organisms.

The book has to be read to follow the many lines of argument. It is a stimulating product. Neither can one overlook the translator of the text, who has done an excellent job in a difficult field.

BENJAMIN HARROW

CITY COLLEGE,  
COLLEGE OF THE  
CITY OF NEW YORK

## SOCIETIES AND MEETINGS

### THE ILLINOIS STATE ACADEMY OF SCIENCE

THE thirty-first meeting of the Illinois State Academy of Science was held at Southern Illinois State Normal University, Carbondale, on May 6 and 7. At the general session on Tuesday morning, President

Roscoe Pulliam, of the Southern Illinois State Normal University, gave a short address of welcome. The members of the academy then listened to the address of the retiring president, Professor Harold R. Wanless, of the University of Illinois, who talked on the subject, "Geological Records of a Rhythmic Nature."

His talk was followed by an address by Dr. M. M. Leighton, chief of the Illinois State Geological Survey, Urbana, whose subject was "Our Exhaustible Resources of Minerals. What Should be the Aim of a Conservation Program?" The final address of this session was given by Dr. Theodore H. Frison, chief of the Illinois State Natural History Survey, on the subject, "Advances in the Renewable Natural Resources Program of Illinois." The Friday morning program of the Junior Academy consisted of the display and the judging of the exhibits by the junior members entered in the annual competition. At the Friday evening general meeting, Dr. T. E. Musselman, of Quincy, addressed the Junior Academy on the topic, "Birds That Hunt and are Hunted," while Dr. John A. Wilson, director of the Oriental Institute of the University of Chicago, Chicago, gave the evening address before the Senior Academy on the subject, "New Spades in Old Soil."

On Friday afternoon 121 papers were presented before eleven sectional meetings. On Saturday the sessions of the meeting consisted of three field trips in the region of Carbondale. The anthropological trip under the direction of Dr. Bruce Merwin and Mr. Irvin Peithman, both of Carbondale, visited some of the many archeological sites of the region. The geological trip, under the direction of Dr. George E. Ekblaw and Mr. J. E. Lamar, of the Illinois State Geological Survey, and Professor H. R. Wanless, of the University of Illinois, visited points of geological interest. The biological trip, which visited the National Forest, Horseshoe Lake and other points of biological interest, was under the direction of Dr. T. H. Frison, chief of the Illinois State Natural History Survey, with the assistance of the other members of his staff, members of the National Forest Service and Mr. Francis D. Hunt, of the State Department of Conservation.

The following resolutions were passed by the academy at its business meeting:

(1) *Resolved*, that the Illinois Academy of Science heartily approves the efforts of the Associated Conservation organizations of Illinois to further the commission plan for the administration of the Department of Conservation in Illinois, and that a copy of this resolution be sent to Don T. Mason, Secretary of the Associated Conservation Organizations of Illinois.

(2) *WHEREAS*: From time to time medical progress is hampered by misleading campaigns for legislation by Anti-Vivisection Societies and whereas the prohibition of humane animal experimentation throttles scientific research into the nature and treatment of diseases common to both animals and man, the Illinois Academy of Science hereby resolves that such activity is ill informed and dangerous to the public well being.

(3) The Illinois Academy of Science desires to record its protest against the introduction into Primeval Na-

tional Parks of any form of commercialism. Embracing only a minute part of our national area, these superb and irreplaceable examples of unique, primitive conditions should be kept inviolate and preserved for the education and inspiration of future generations. The Illinois Academy urgently petitions all state and federal officers, and especially, the President of the United States, and members of his cabinet, as well as members of Congress, to oppose resolutely the granting of permits allowing such privileges in these parks. It is hereby resolved that a copy of these resolutions be sent to the President. Also to the members of the Cabinet, to Illinois Senators, and Representatives in Congress, and that they be furnished to all societies and persons interested in the National Parks.

(4) *WHEREAS*: It is necessary for the conservation of archeological and historical sites in Illinois that a law be enacted by the General Assembly providing for the licensing of all persons or institutions who desire to excavate prehistoric sites, ancient burial grounds, or any site of importance to the history of Illinois; *be it resolved* that the Committee for Conservation of Archaeological and Historical Sites be empowered to confer with the Director of Registration and Education, and to draw up a bill for submission to the council of the Academy for its approval.

(5) *Resolved*, that the Academy reaffirms its past position with respect to emphasizing the importance of the research agencies of the State, and that they continue their sound and thoroughgoing researches on the natural resources of the State with a view to more intelligent development and conservation.

The officers elected for next year are:

*President*, George D. Fuller, botany, University of Chicago.

*First Vice-president*, Evelyn I. Fernald, botany, Rockford College.

*Secretary*, Robert F. Paton, physics, University of Illinois.

*Treasurer*, Paul D. Voith, botany, University of Chicago.

The next annual meeting will be held in Springfield, Ill., on May 5 and 6, 1939.

ROBERT F. PATON,  
*Secretary*

#### THE NORTH CAROLINA ACADEMY OF SCIENCE

THE thirty-seventh annual meeting of the North Carolina Academy of Science was held at the North Carolina State College of Agriculture and Engineering of the University of North Carolina, Raleigh, N. C., on May 6 and 7, 1938. The meeting was exceptionally well attended by members and visitors. Ninety papers and several exhibits made up a record program.

Because of the large number of titles, especially in the field of botany, it was necessary to create two new sections, one for botany and one for zoology.

The General Section met at 9:30 A.M. on the first

day for the presentation of papers of general interest and continued, except for the luncheon hour, till 4:30 P.M. The Botany Section met from 2:00 to 4:30 P.M. on the first day.

The annual business meeting was held at 4:30 P.M., on May 6. At this meeting, resolutions of respect were read in honor of the memories of Mrs. Edna Metz Wells and Dr. William Louis Poteat. The executive committee reported the election of sixty-six new members and the reinstatement of thirteen former members.

In the high school science essay contest, sponsored by the academy, the first prize was awarded to Larry Hardin, Boyden High School, Salisbury, N. C., for his essay entitled "Science in Aviation."

Dr. Herbert F. Prytherch of the U. S. Bureau of Fisheries, Beaufort, N. C., was awarded the medal for the most noteworthy paper on the 1938 program. The title of Dr. Prytherch's paper was "Life Cycle of a Sporozoan Parasite of Oyster." The American Association for the Advancement of Science research grant was awarded to Dr. Henry W. Jensen, of the Asheville Farm School, for his project on "continuation of a study on the evolution of the dioecious flora of the southern Appalachians with special reference to the function of the chromosomes in sex determination."

The issuing of an annual membership card to each member in good standing was authorized by the academy.

The constitution for the academy was amended in such a way as to recognize three kinds of memberships, as follows: (a) active membership; (b) active scientific organizations membership; (c) life membership.

In the evening of the first day a complimentary picnic supper was extended to the members of the academy in Pullins Park by the North Carolina State College. Dr. M. L. Braun, vice-president of the academy, presided at the evening meeting. An address of welcome was given by Colonel J. W. Harrelson, dean of the administration of State College, after which Dr. W. E. Speas, of Wake Forest College, gave his presidential address, entitled "The Father of Nuclear Physics." This was followed by an informal reception by the State College Woman's Club.

In the forenoon of the second day the academy met in the following sections: General, Botany, Zoology, Mathematics, Physics, and the North Carolina Section of the American Chemical Society.

The following officers of the academy were elected for next year:

*President:* John W. Lasley, Jr., University of North Carolina.

*Vice-President:* Donald B. Anderson, North Carolina State College of the University of North Carolina.

*Secretary-Treasurer:* H. L. Blomquist, Duke University.

*Executive Committee:* The above officers and W. L. Porter, Davidson College; R. F. Poole, North Carolina State College of the University of North Carolina; and O. C. Bradbury, Wake Forest College.

*Representative to the A. A. A. S.:* Bert Cunningham, Duke University.

The following officers were elected by the various sections:

#### CHEMISTRY SECTION

*Chairman:* Neville Jones, Wake Forest College.

*Vice-Chairman:* E. C. Markham, University of North Carolina.

*Secretary-Treasurer:* Ivan D. Jones, North Carolina State College of the University of North Carolina.

*Councilors:* R. W. Bost, University of North Carolina, and D. G. Hill, Duke University.

*Members of the Executive Committee:* W. C. Vosburgh, Duke University; Edward Mack Jr., University of North Carolina; and Walter Jordan, North Carolina State College of the University of North Carolina.

#### MATHEMATICS SECTION

*Chairman:* R. C. Bullock, North Carolina State College of the University of North Carolina.

*Secretary:* E. A. Cameron, University of North Carolina.

#### PHYSICS SECTION

*Chairman:* W. E. Speas, Wake Forest College.

*Secretary:* F. W. Lancaster, North Carolina State College of the University of North Carolina.

#### ZOOLOGY SECTION

*Chairman:* Bert Cunningham, Duke University.

*Secretary:* Z. P. Metcalf, North Carolina State College of the University of North Carolina.

The Botany Section did not elect officers but left the appointment of officers to the executive committee.

The thirty-eighth annual meeting of the North Carolina Academy of Science will be held in 1939 at Wake Forest College, Wake Forest, North Carolina.

H. L. BLUMQUIST,  
*Secretary*

## SPECIAL ARTICLES

### THE CHROMOPROTEINS OF PHOTOSYNTHETIC PURPLE BACTERIA<sup>1</sup>

It is well known that chlorophyll extracted from

<sup>1</sup> From the Department of Biological Chemistry, Harvard Medical School, Boston, Massachusetts, and the Cruft

leaves with organic solvents has undergone alteration through the process of extraction, because the absorption bands of such solutions are displaced about 20 mμ

Laboratory, Harvard University, Cambridge, Massachusetts.

from their position when the chlorophyll is in the cells. Herlitzka<sup>2</sup> has made water soluble extracts of chlorophyll from spinach without changing the optical properties, and Lubimenko<sup>3</sup> has pointed out that chlorophyll occurs naturally in combination with a protein. Stoll<sup>4</sup> calls this compound "chloroplastin." Wurmser, Levy and Tessier<sup>5</sup> have obtained such a water solution of colored protein from ground cultures of photosynthetic purple bacteria. It is not yet possible to make a mixture of known or unknown composition which will reduce CO<sub>2</sub> with visible light in a manner comparable to the process in the living plant. The advances in the knowledge of cellular respiration and especially fermentation were based on the discovery of active cell-free extracts by Buchner.<sup>6</sup> Photosynthesis is still in the pre-Buchner stage. The study of the photosynthetic pigments in their naturally occurring form rather than as derivatives prepared by the extraction process is the first obvious step in the search for a photochemically active extract. The present discussion deals with a better method of preparing water solutions of these pigments from bacteria, and describes the properties of such solutions and their spectral absorption curves.

High frequency vibrations have been used by a number of workers for breaking open bacteria, marine eggs and tissue cells to liberate the enclosed constituents. Through the courtesy of Professor G. W. Pierce and his collaborators in the Cruft Laboratory, I have had access to a powerful magnetostrictive vibrator and have found that sound waves of a frequency of 15,000 or 21,000 cycles per second will break open purple bacteria in a few minutes, freeing the cell sap which contains a water soluble colored protein. The white cellular debris can be centrifuged off from the deep brown or red liquid leaving a slightly opalescent solution. The solution does not have the capacity to reduce carbon dioxide as does the original suspension of bacteria.

Experiments were made with *Streptococcus varians* and *Spirillum rubrum*, both of which have been used for recent work on photosynthesis.<sup>7</sup> A suspension of *Streptococcus varians* was put in the vibrator cup and samples taken at different times after the vibrator was started. The photosynthetic capacity, measured manometrically, and the amount of extracted pigment, measured spectrophotometrically, were determined for

each sample. During the treatment with sound waves, the destruction of photosynthesis runs an identical course with pigment liberation. It is likely that some of the enzymes responsible for the non-photochemical steps are spoiled by this treatment, since it is believed that the pigment is not appreciably changed by such extraction methods.

In order to study the absorption spectrum of the pigment, a photoelectric spectrophotometer was constructed.<sup>8</sup> A Hilger constant deviation spectroscopy with a dense flint glass prism was fitted with an exit slit, making the instrument into a monochromator. The spectroscopy was intended for the visible spectrum out to 800 mμ, but since it was desired to extend the range, the prism was shifted in relation to the wavelength scale and recalibrated photographically, so that it could be used out to 1,000 mμ, which is also about the limit obtainable with the Cesium photocell. Light from a 6-volt, straight coil, street lighting lamp passed through the monochromator and, before falling on the photocell, went through an absorption vessel mounted in a sliding rack to facilitate the interchange of pigment solution and solvent. The collimator arm of the spectroscopy stuck into a grounded light tight metal box containing the absorption vessel rack, photocell and one tube amplifier. The current from the amplifier was read on a galvanometer.

The width of the spectral range giving 100 mm deflection of the galvanometer was roughly 2 mμ at 700, but rose to 10 mμ at 1,000, and at 400 mμ. The precision of the deflection reading is about  $\pm 1$  per cent.

A curve has been given for the pigments in live *Spirillum rubrum* (see footnote 7) in the visible region and crude measurements were made in the infra red. With this spectrophotometer, more accurate determinations have been made on the supersonic extracts of this species. Ten liters of culture were obtained, and the bacteria centrifuged out, then broken open by supersonic vibration. This solution was used for the absorption curve shown in Fig. 1 and for most of the following work. The three infra red bands, 960, 875 and 790 mμ, the yellow one at 590 mμ and the blue one at 420 mμ, are due to bacteriochlorophyll, a substance found by Schneider,<sup>9</sup> and by Fischer and collaborators<sup>10</sup> to be similar to ordinary chlorophyll. It is a magnesium porphyrin compound, but has different side chains from chlorophyll. The bands at about 545,

<sup>2</sup> A. Herlitzka, *Biochem. Z.*, 38: 321, 1912.

<sup>3</sup> V. N. Lubimenko, *Rev. Gen. Bot.*, 39: 547, 1927 ff.

<sup>4</sup> A. Stoll, *Naturwissenschaften*, 24: 53, 1936.

<sup>5</sup> R. Wurmser, R. Levy and G. Tessier. *Ann. de Physiol. et de Physico-Chimie Biologique*, 1: 298, 1925.

<sup>6</sup> E. Buchner, H. Buchner and M. Hahn, "Die Zymasegärung." Munich and Berlin, 1903.

<sup>7</sup> C. S. French, *Jour. Gen. Physiol.*, 20: 711; 21: 71, 1937.

<sup>8</sup> It is a pleasure to thank Professors T. Lyman and O. Oldenberg and Dr. W. M. Preston for their kind assistance. I am also very grateful to Professor A. B. Hastings for many helpful suggestions throughout the work.

<sup>9</sup> E. Schneider, *Z. Physiol. Chem.*, 226: 221, 1934; *Ber. d. Deutsch. bot. Ges.*, 52: 96, 1934.

<sup>10</sup> H. Fischer, W. Lautsch and K.-H. Lin, *Annalen*, 534: 1, 1938.

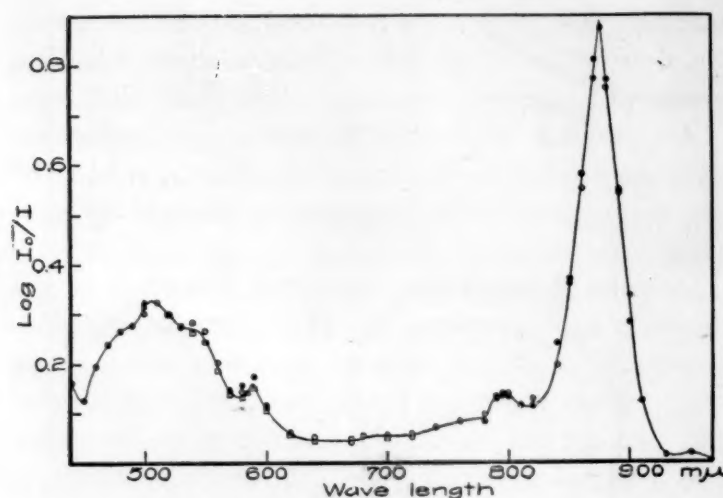


FIG. 1

510 and 480  $m\mu$  are due to Spirilloxanthin, a substance prepared in crystalline form from this species by Van Niel and Smith,<sup>11</sup> who found it to be red carotinoid with 15 double bonds. Only light absorbed by the green pigment is used for photosynthesis.

The question is now raised whether this colored extract is the same as the pigment in the intact cells. To test this, the infra red absorption curve of the intact pigment in the cells was measured by using a light scattering control of cells bleached with  $H_2O_2$ , and compared with the curve obtained from the super-sonic extract. This experiment was done with *Streptococcus varians*; it shows exact agreement in position of the infra red bands in the bacteria and in the extract, and roughly about the same height as indicated in both curves in Table 1. Considering the ap-

TABLE 1

RELATIVE ABSORPTION COEFFICIENTS FOR *in vivo* AND EXTRACTED BACTERIA PIGMENT OF *Streptococcus varians*

	795 $m\mu$	855 $m\mu$
Intact pigment .....	5.8	15.3
Extracted pigment .....	7.7	18.1

proximate nature of the scattering control, the height agreement is quite satisfactory. As far as light-absorbing capacity is concerned, the extract is closely similar to the intact pigment which is not true for extracts made with organic solvents.

The extract of *Spirillum rubrum* was diluted with buffers of various pH values and the mixtures centrifuged free of precipitate. The absorption of the solutions was then measured at 875  $m\mu$  to determine the pigment concentration. There is a region of insolubility between pH 3.0 and 4.5. The pigment is precipitated by 0.5 saturated  $(NH_4)_2SO_4$ .

As far as I can tell by fractional precipitation and adsorption experiments, both the green bacteriochlorophyll and the red spirilloxanthin are attached to the

<sup>11</sup> C. B. van Niel and J. H. C. Smith, *Arch. f. Mikrobiol.*, 6: 219, 1935.

same or to similar protein molecules, for it has not yet been possible to separate out fractions of different color. Since Stoll's (see footnote 4) name of "chloroplastin" can hardly be applied to pigments from organisms such as bacteria and blue green algae which do not have chloroplasts, I would suggest the term "photosynthin" as a general name for compounds of photosynthetic pigments such as bacteriochlorophyll with protein and use "chloroplastin" specifically for such compounds containing ordinary chlorophyll from higher plants and yellow green algae.

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## RESPIRATION OF WHEAT INFECTED WITH POWDERY MILDEW

WHEAT seedlings infected with the powdery mildew, *Erysiphe graminis tritici*, soon show visible symptoms of physiological derangement and die in three to four weeks if kept at 18–22° C. This paper reports a preliminary study of respiration in healthy and mildewed wheat.

Control and infected seedlings of Marquis wheat were grown at 20° C. in adjacent compartments of a chamber lighted from above by a 1000-watt Mazda bulb. Inoculation with mildew occurred when the first leaf was fully expanded. Oxygen consumption of healthy and inoculated primary leaves at 20.5° C. was measured by means of Warburg manometers at frequent intervals over a period of three and a half weeks.

Fig. 1 shows that after inoculation the respiration

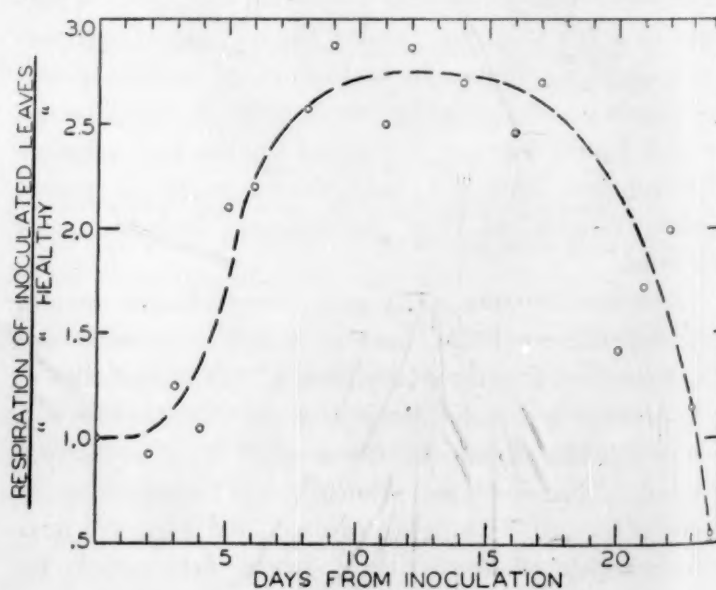


FIG. 1

rate of infected leaves rose rapidly and reached a maximum value 2.5–3.0 times that of the controls in about 9 days. The rate of respiration was maintained at a high value for about a week, and then began to decline, finally falling considerably below that of the controls. Table 1 shows that fungus respiration was

TABLE I

RESPIRATION OF MILDEWED AND HEALTHY WHEAT LEAVES  
WITH AND WITHOUT SULFUR TREATMENT.  
TEMPERATURE 20.5° C.

Days after inoc.	C. mm. O <sub>2</sub> /cm. <sup>2</sup> /hr.					
	Mildewed plants			Mildew free plants		
	Sulfur for 0 hrs.	12 hrs.	28 hrs.	Sulfur for 0 hrs.	12 hrs.	28 hrs.
6-7 ..	8.6	8.4	8.3	4.2	3.8	4.1
12-13 ..	8.5	8.0	8.0	3.2	3.2	3.3

insufficient to account for the increased oxygen consumption of mildewed leaves, since dusting with finely pulverized sulfur, which quickly destroys the mildew,

caused little decrease in respiration. Thus, infection of wheat leaves by mildew markedly increased the rate of oxygen consumption by the host tissues. Clover leaflets infected with powdery mildew also respire more rapidly than controls, even when the fungus has been killed by sulfur dust.<sup>1</sup> Although the mildew penetrates only the epidermal cells, Allen and Goddard,<sup>2</sup> in this issue of SCIENCE, show that the increase in respiration occurs principally in the mesophyll tissues of the host.

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## SCIENTIFIC APPARATUS AND LABORATORY METHODS

### A MICRO-METHOD FOR MEASURING SPECIFIC CONDUCTANCE

RECENT trends in biological research have emphasized the importance of a knowledge of the physical properties of various biological fluids. Unfortunately, although excellent methods for the measurement of specific conductance, surface tension, etc., are known, these generally involve the use of such large quantities of the fluid to be tested that they are impractical for the biologist.

In connection with some as yet unpublished investigations dealing with the specific conductance of the extra-embryonic fluids of the developing chick, the following method was employed. The essential elements of the apparatus are an approved type of alternating current bridge and a special type of conductance cell designed for the measurement of small volumes of fluid. The importance of the type of apparatus used is emphasized and discussed in detail by Jones and Josephs<sup>1</sup>. The bridge consists of arms of two matched Ayrton cards (General Radio Co., Cambridge, Mass.) giving an equal-arm, direct-reading bridge. A non-inductively wound resistance box was used (Leeds-Northrup Co. No. 202886). This was equipped with six dials, permitting of measurements to hundredths of an ohm. Connected in parallel with this resistance box was a 45-plate variable air condenser for balancing out the capacitative effects of the conductance cell located in the opposite arm of the bridge. The cell itself will be described below.

The oscillator used was the one specified by Jones and Josephs, and it, together with a three-stage amplifier in the input leads, was encased in a grounded metal filing cabinet drawer, an effective electrostatic shield. Although measurements were possible at frequencies of from 400 to 4,500 cycles, for the sake of convenience a frequency of 1,000 cycles per second was employed.

<sup>1</sup> G. Jones and R. C. Josephs, *Jour. Am. Chem. Soc.*, 50: 1049-1092, 1928.

Inserted between the bridge proper and the telephones was a three-stage amplifier (manufactured by Magnavox). Grounded metal shields separated this piece of apparatus, the resistance box and the variable condenser from the ratio arm of the bridge and from each other. The telephones were grounded in the manner recommended by Jones and Josephs. All the equipment (except the water bath, conductance cell and its leads to the bridge) was placed within a large grounded wire cage, in which the observer stood upon an insulating fiber platform while making readings.

In the designing of the conductance cell, the recommendations of Jones and Bollinger<sup>2</sup> were followed in so far as possible. On account of the small volumes of fluid to be tested, a considerable number of modifications had to be made. It was found necessary to reduce the area of the electrodes and also to shorten the distance between them to permit the measurement of volumes as small as 0.1 cc. The design finally adopted is shown in Fig. 1. A piece of Jena glass tubing, 2 centimeters long and 0.3 centimeter in diameter, was selected for the central portion. The ends were sealed and the filling tubes and tubes for mercury added. The electrodes consist of tight coils of platinum wire, about a square millimeter in area, set a distance of one centimeter apart. The working volume of this cell is approximately 0.07 cubic centimeter. These modifications would theoretically result in an increase in the error due to capacitative shunt, but inasmuch as the liquid under test is run in from one side only, and since it barely fills the central portion of the cell, there will be, at the most, only a thin film of liquid in one filling tube. Whatever small increase this film may produce is easily balanced out by tuning the variable condenser in the opposite arm of the bridge. To control the experimental tem-

<sup>1</sup> C. E. Yarwood, *Jour. Agr. Res.*, 49: 549, 1934.

<sup>2</sup> P. J. Allen and D. R. Goddard, *SCIENCE*, in press.

<sup>2</sup> G. Jones and G. M. Bollinger, *Jour. Am. Chem. Soc.*, 53: 411-451, 1931.

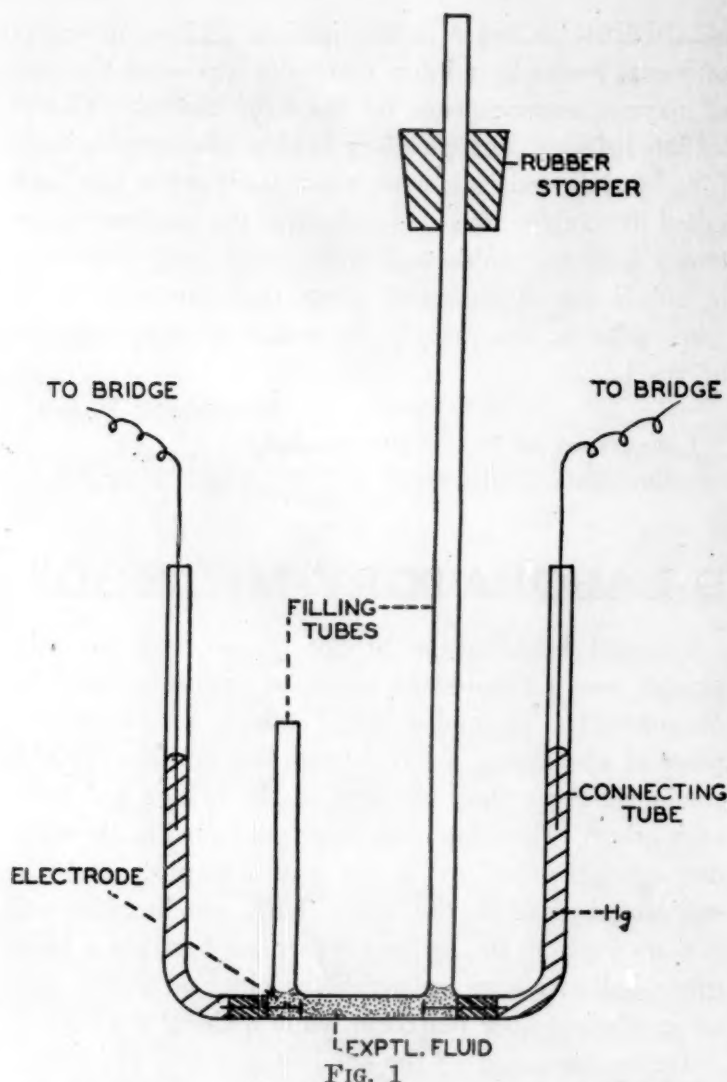


FIG. 1

perature, the cell was suspended in a water thermostat capable of regulation to  $\pm 0.1^\circ \text{C}$ .

The subject of polarization resistance and its significance in experiments on electrical conductance has been discussed by Jones and Christian,<sup>3</sup> and they show how one may determine the exact magnitude of this error at any given frequency for any given cell. Accordingly, the cell was filled with 0.1M KCl and its resistance measured at various frequencies. The measured resistance at a frequency of 1,000 cycles was found to be 1187.0 ohms; correcting for the polarization error according to their method, the true resistance was found to be 1182.9 ohms, indicating a percentage error of 0.346 per cent.

Jones and Bollinger<sup>4</sup> have made a quantitative study of platinization of electrodes and recommend a degree of platinization represented by from 5.94 to 12.73 coulombs per square centimeter of electrode surface. Following their paper, the cell was filled with platinizing solution and a current of 0.004 ampere passed through it, with a reversal of polarity every ten seconds, for a total time of one minute. Thus, each electrode acted as a cathode while 0.12 coulomb, or 12

<sup>3</sup> G. Jones and S. M. Christian, *Jour. Am. Chem. Soc.*, 57: 272-280, 1935.

<sup>4</sup> G. Jones and D. M. Bollinger, *Jour. Am. Chem. Soc.*, 51: 280-284, 1935.

coulombs per square centimeter, were passing. Such a degree of platinization imparts a distinct dusky hue to the electrodes. Moreover, electrodes platinized to this extent gave consistent readings on various test solutions over considerable periods of time.

The conductance cell may be standardized by measuring its resistance when filled with a solution of known specific conductance, for example, 0.1M KCl which has a specific conductance of 0.01167 mhos per cm at  $20^\circ \text{C}$ . (the experimental temperature). In making up this solution, Merck's chemical was used, with stated total impurities of 0.0458 per cent. It was therefore deemed unnecessary to attempt further purification. The measured resistance of this solution was found to be 1187.0 ohms, or to correct for polarization, 1182.9 ohms. Measurements made at approximately weekly intervals throughout the course of the experiments showed no deviations from this value. Measured resistance and specific conductance are related according to the following equation:

$$R = \frac{L}{A} \times \frac{1}{k}$$

where  $R$  is the measured resistance  
 $L$  is the distance between the electrodes  
 $A$  is the cross-sectional area of the cell  
 $k$  is the specific conductance

The term  $L/A$  is also known as the Cell Constant,  $C$ , or

$$C = R \times k$$

In the case of the cell described above,  $C = 1182.9 \times 0.01167$  or  $13.804 \text{ cm}^{-1}$ . Once having determined the Cell Constant, it is possible to obtain the specific conductance of any desired solution merely by measuring its resistance (and correcting for polarization errors) and dividing the Cell Constant by this figure, viz.:

$$k = C/R$$

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